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Structure and Stratigraphy of a Complex Anticlinal Feature, Backbone Anticline, Arkoma Basin, Arkansas

Structure and Stratigraphy of a Complex Anticlinal Feature, Backbone Anticline, Arkoma Basin, Arkansas

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Geology

by

Shailyn Abbott
Arkansas Tech University
Bachelor of Science in Geology, 2010

May 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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Thesis Committee

ABSTRACT

The Arkoma Basin of Arkansas and Oklahoma formed in the Ouachita foreland during the late Mississippian and Pennsylvanian periods (about 290-to 330 million years ago). The basin developed in response to convergent tectonic boundaries that closed obliquely from west to east associated with Ouachita orogenic event. The Backbone anticline in the northern Arkoma Basin is a prominent product of this convergence, and represents the first major component of this study. The structure is asymmetric with beds on the southern limb dipping steeply to the south. It is also expressed topographically as a prominent ridge that trends eastward from the Oklahoma-Arkansas border approximately 30 miles. The ridge is bounded on the northern side by a steeply dipping normal fault with most of the sedimentary exposure occupying a position on the southern hanging wall of the structure. Strata involved in the structure are sandstone and shale units from the middle and upper part of the Atoka Formation. A recent road cut in southern Sebastian County, Arkansas exposes a complete and continuous section of more than 600 feet in thickness through an upper Atoka sandstone unit along the Backbone anticline.

A subsurface stratigraphic study of the middle of the Backbone anticline was also conducted. Several normal and some reverse faults were noted from cross-sections of the subsurface using IHS PETRA ® software program. The upper 5400 feet of the Atoka Formation includes intervals from the middle and upper part of the formation. This interval extending from the Casey Sand to the Upper Alma Formation was examined by means of three cross-sections prepared from wire line logs to determine the role of faulting in the sedimentary section.

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Last but not least, I would like to thank Hanna Oil and Gas for their generosity and letting me use their facility for my thesis study. They helped me whenever I needed it and gave me a sneak peek on exactly what the next chapter of my life will be in the oil and gas industry. Thank you!

TABLE OF CONTENTS

I. INTRODUCTION……..……..……....1

A. AREA OF STUDY…….…..……..…..3

II. GEOLOGIC SETTING……..…..……..……6

A. OUACHITA OROGENY…….……..……..…...6

B. ARKOMA BASIN…….…..…….……....7

C. TECTONICS……..……...……9

III. STRATIGRAPHY……..……..……..……13

A. REGIONAL STRATIGRAPHY……..…..……..15

B. LOCAL STRATIGRAPHY……..……..……...……..15

Atoka Formation……..……..……..17

Hartshorne Sandstone……..…..……..……....17

IV. FAULT NOMENCLATURE……..……..……..19

V. METHODS……..……..20

A. WIRELINE LOGS……..……...20

B. CROSS-SECTIONS……..……..……..21

VI. DISCUSSION…….…..….24

Cross-Section A-A'…….……..……..24

Cross-Section B-B'…….……...25

Cross-Section C-C'…….……...25

VII. CONCLUSION…….…….....29

VIII. REFERENCES…….…….……...…31

VIIII. APPENDIX I: Correlated Cross-Sections with Maps…….……....…….32

X. APPENDIX II: List of Wells Used in Study…….……...……40

I. INTRODUCTION

The Ouachita Orogeny (Mississippian and Pennsylvanian periods) was caused by the collision of North America and an unknown southern terrain. It consists of modern day separately eroded ranges like the Arbuckles of central Oklahoma and the Marathons in West Texas. The collisions of continents formed the Arkoma Basin. The Arkoma Basin is located in central Arkansas into central Oklahoma (Figure 1) and is characterized by broad synclines separated by narrow anticlines (Houseknecht, 1986). It is dominated by strata of the Atoka Formation, a thick succession of sandstone and shale units that record a transition from a stable shelf to a foreland basin. Atoka strata thicken from a few feet in northern Arkansas to greater than 23,000 feet in the south adjacent to the Ouachita fold belt (Zachry and Sutherland, 1984). Much of the subsidence of the Arkoma Basin occurred during deposition of middle Atoka strata as the lower Atoka shelf was broken by large, normal faults with down to the south displacement (Houseknecht, 1986). The basin also contains the Hartshorne Sandstone Formation, a thick sandstone as well as overlying beds of Desmonian age that overlie the Atoka and the McAlester Formation, a shale unit above the Hartshorne. Strata of the Arkoma basin and Ouachita orogenic belt reflect the opening and subsequent closing of a Paleozoic ocean basin on the southern edge of what is now the North American continent. Carboniferous strata of the region were deposited during the final phase of ocean basin closing, and record the transition from sedimentation on a passive, rifted margin to synorogenic sedimentation in a rapidly evolving foreland basin (Houseknecht, 1986). The Backbone anticline is one of several anticlines located north of the Ouachita orogenic belt in the Arkoma Basin. Listric thrust faults underlie much of the folded section and ramp to the surface along the crests of many anticlines (Houseknecht, 1986). This study was to focus

primarily on the Backbone anticline and the strata below. This document will include studies and results from the center of the Backbone anticline using the IHS PETRA® software program. The research includes studies from the well logs obtained in the area, constructed cross-sections from research, and data obtained about the thrust faults in the area.

Figure 1: Map showing the location of the Arkoma Basin (Newfield Exploration Company, 2007).

A. AREA OF STUDY

The Backbone anticline is approximately 17 miles long and 2.5 miles wide. The furthest most west is 35°10’47.85” N latitude, and 94°35’22.16” W longitude, with an elevation of 620 feet above mean sea level. The east side of the backbone anticline is 35°14’19.71” N, 94°28’06.31” W at elevation of about 685 ft. Corners of the rectangular area of study are 35°13’45.11”N, 94°21’23.14” W to 35°13’42.60 N, 94°17’30.83” W. It lies in 7N 31 W section numbers 31,32,33,34 and 6N 31W section numbers 3,4,5,6,7,8,9,10 township and ranges (Figure 2). It extends from Oklahoma into Arkansas verify based on what you provided in the abstract.

The study area is in the center of the eastern part of the Backbone anticline. The structure is located in the Arkansas River Valley physiographic province in gently to moderately deformed Paleozoic sedimentary rock that lie between the Ozark Plateau/Boston Mountain region of flat-lying strata in northern Arkansas and the heavily deformed Ouachita Mountain region of west-central Arkansas.

The well logs that were used to conduct research of the area were assembled from the Arkansas Oil and Gas Commission in Fort Smith Arkansas. Fifty wireline well logs were obtained and included wells from Stephens Production Company, Hanna Oil and Gas, Highland Oil and Gas, Foundation Energy, XTO Energy, Inc. and Chesapeake Energy (Figure 3).

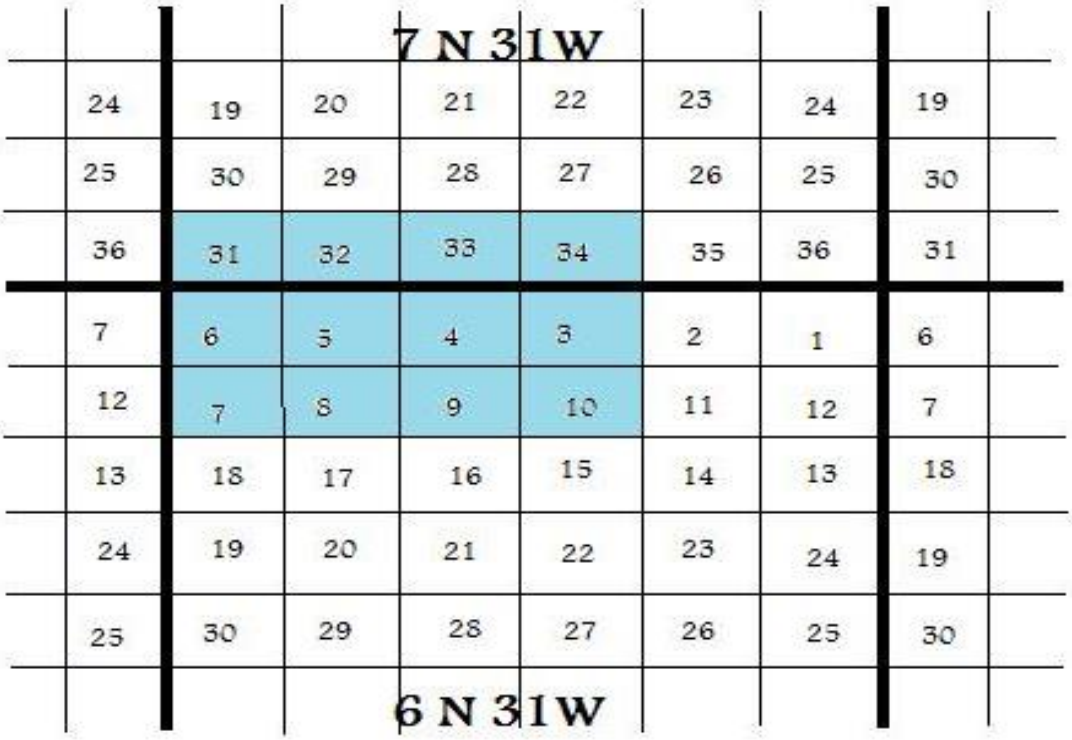

Figure 2: Location of study area in Sebastian County showing townships, ranges and section numbers (in light blue)(made by author).

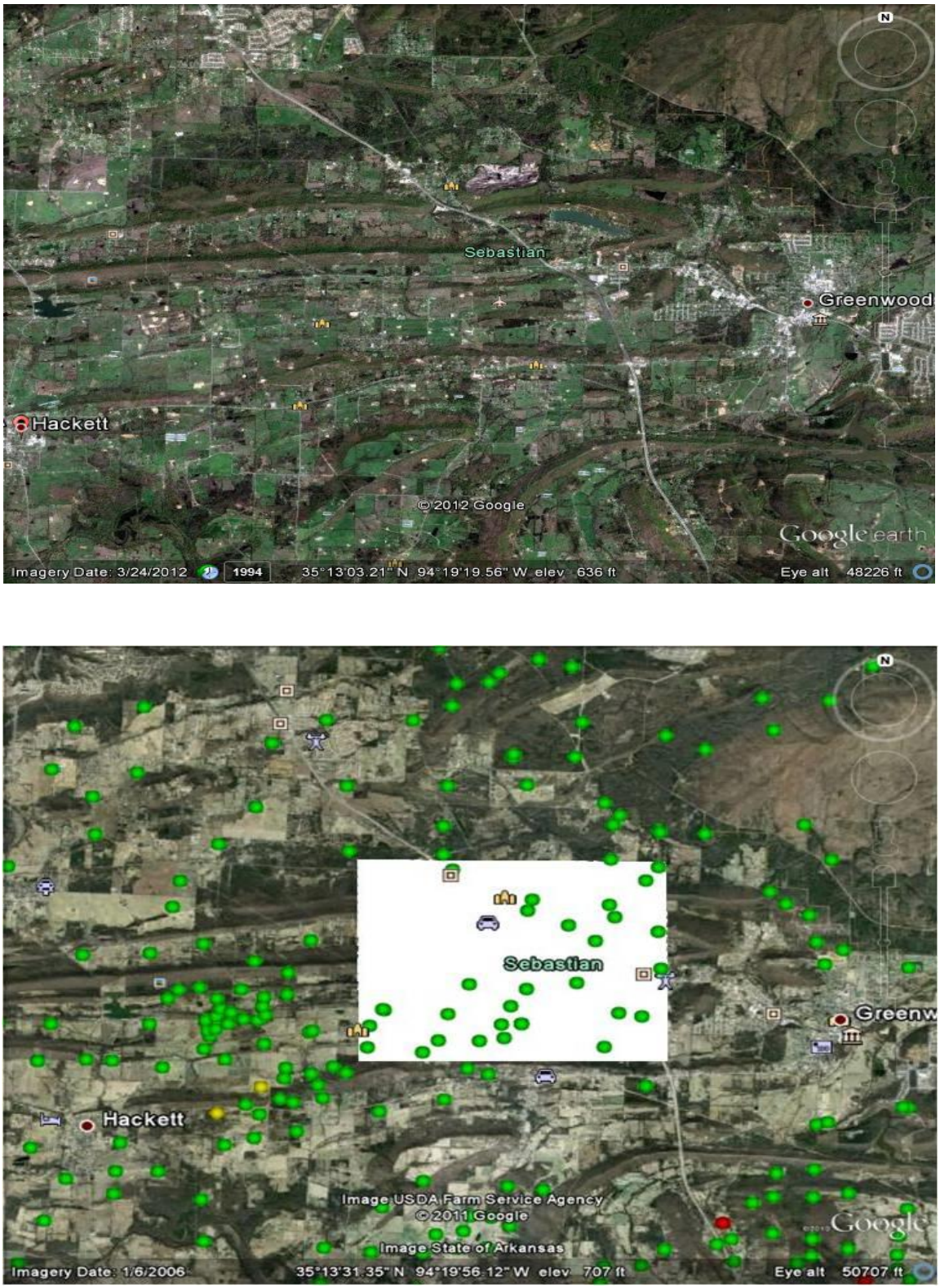

Figure 3: Images taken from Google Earth showing the area of study along the backbone anticline (white square). Also, showing the well logs obtained for study (green dots).

II. GEOLOGIC SETTING

A. OUACHITA OROGENY

The Ouachita Orogen marks the southern boundary of the Arkoma Basin. It trends eastward from southeastern Oklahoma to south-central Arkansas. Highly deformed Paleozoic strata have been thrust over the southern margin of the North American craton in numerous imbricate thrust sheets (Houseknecht et al, 1986). It marks the collision of North America with an unknown terrain.

The Ouachita system today consists of several eroded ranges (Ouachitas-Arkansas, Arbuckles-central Oklahoma, and Marathons-west Texas). The final phases of Ouachita orogenies segmented the foreland region into individual structural basins, one of which is the Arkoma (Houseknecht, 1986) (Figure 4).

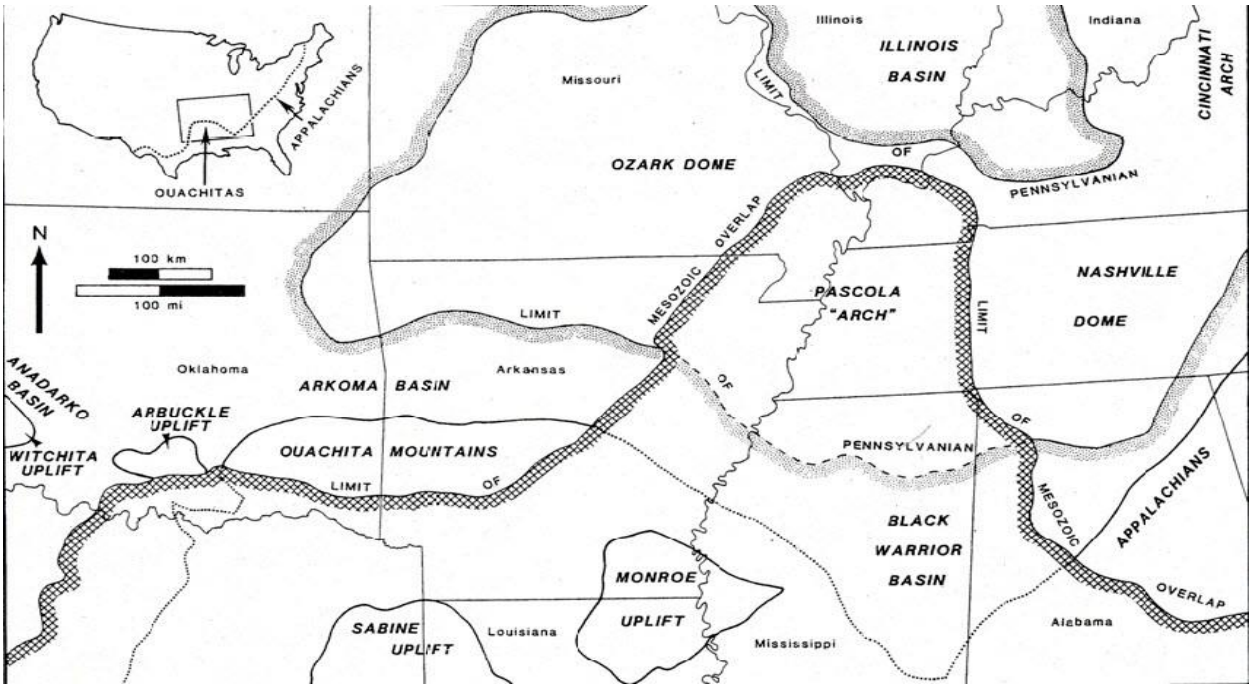

Figure 4: Map showing the position of the Arkoma Basin relative to the Ouachita orogenic belt. The Mesozoic overlap is illustrated. (Houseknecht et al., 1986)

B. ARKOMA BASIN

The Arkoma Basin lies immediately north of the Ouachita orogenic belt. The southern section of the Arkoma Basin is "historically defined" as the northern part of the Ouachita frontal thrust belt. The older part of the Arkoma Basin is to the south and extends under the frontal thrust belt for an unknown distance (Houseknecht, 1986). During Early and Middle Atokan time, the southern margin of the Arkoma shelf was subjected to flexural bending, caused by continued basin subsidence to the south, that eventually resulted in the development of large east-trending syndepositional normal faults that ceased at the end of the Middle Atoka deposition (Sutherland, 1988) (Figure 5 and 6).

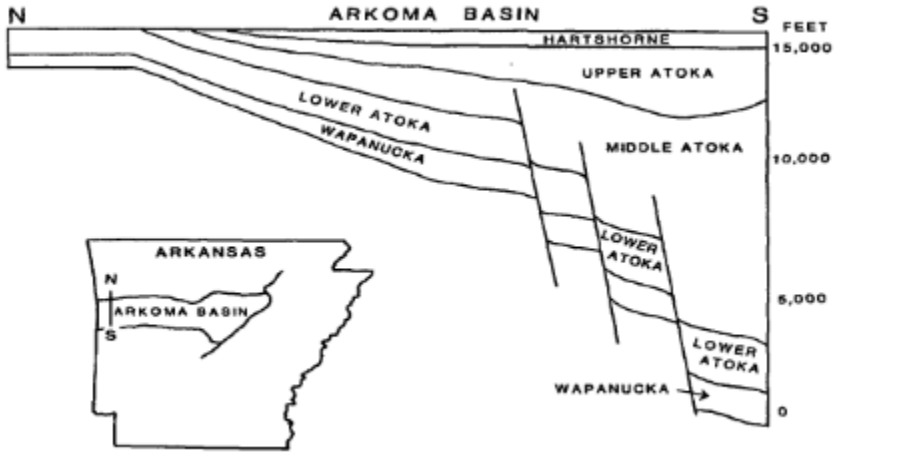

Figure 5: Arkoma Basin's north-south cross-section illustrating the deposition of the Middle Atoka Formation as a result of the presence of syndepositional faults (Zachry and Sutherland, 1984).

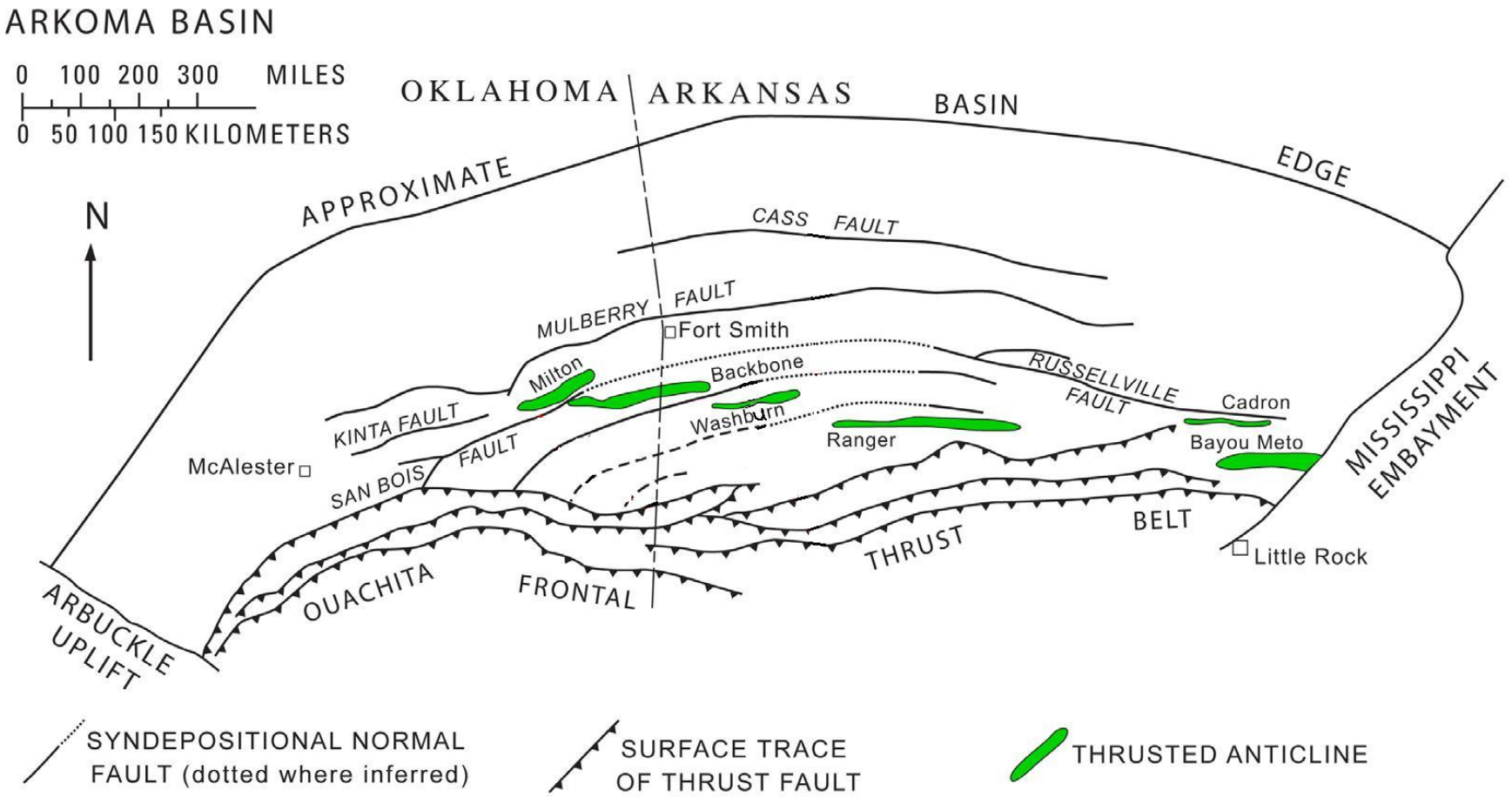

Figure 6: Map showing location of the Backbone anticline and major thrust and normal faults in the Arkoma Basin area (Houseknecht, 1986).

C. TECTONICS

Collision between the southern margin of North America and another continental plate (Sabine terrain) created major geologic provinces. For example, the Ouachita Mountains in Arkansas, the Arbuckles in central Oklahoma and the Marathons in west Texas. This episode concluded with southward sloping subduction zone (Figure 7).

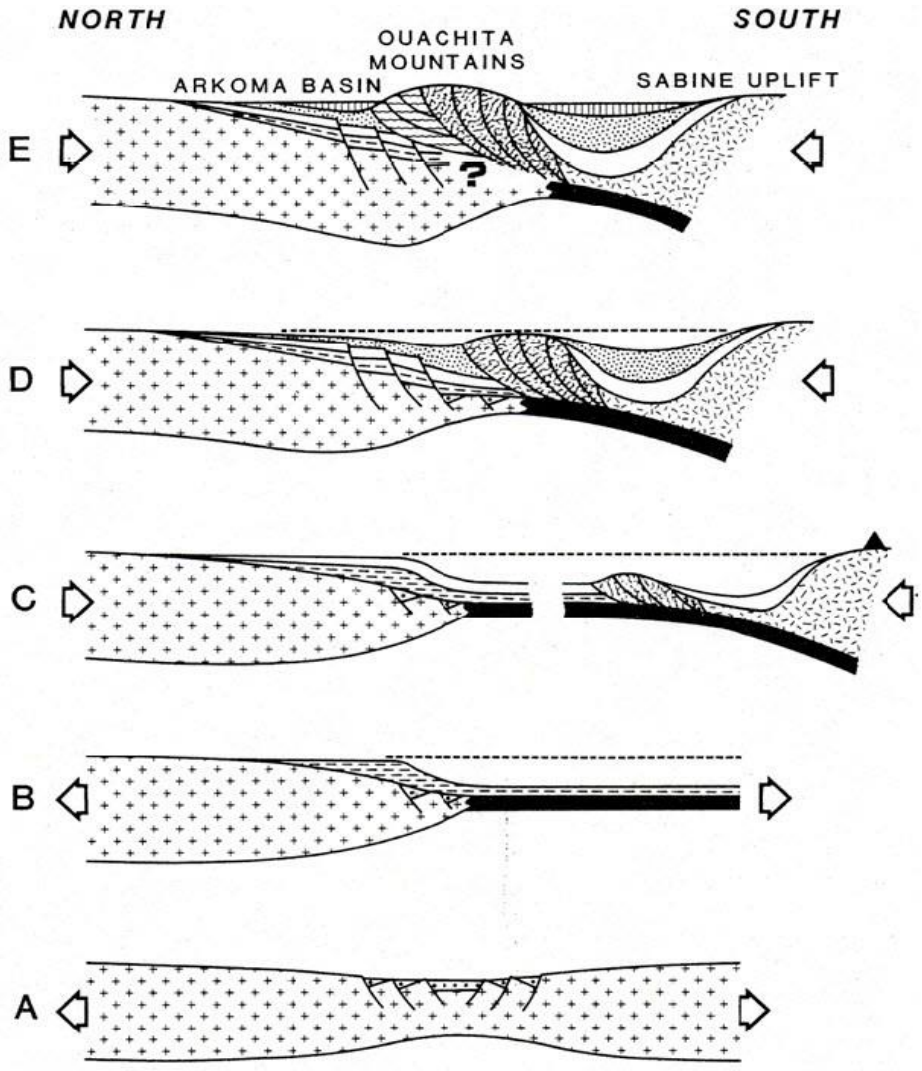

Figure 7: Hypothetical cross-sections depicting tectonic evolution of the southern margin of North America. (A) late Precambrian-earliest Palaeozoic, (B) late Cambrian-earliest Mississippian, (C) early Mississippain-earliest Atokan, (D) early-middle Atokan, and (E) late Atokan-Desmoinesian (Houseknecht and Matthews, 1985).

An opening of an oceanic basin during the latest Precambrian or earliest Palaeozoic was indicated by a major episode of rifting (Figure 7A). Figure 7B shows the consequence of this rift opening, where in the southern margin of North America evolved into an Atlantic-type margin that persisted through the middle Palaezoic (Houseknecht, 1986).

The oceanic basin began to close, as a result of the southward subduction under the Sabine terrain (Figure 7C). This event started during the Devonian or early Mississippian. With this tectonic convergence, the development of the Ouachita orogenic belt began as an accretionary prism. An accretionary prism is scraped off material usually from an oceanic plate and is left on the subducting plate. It lies on top of the convergent plate. Also, during this time (Mississippian), slow sedimentation in marine and non-marine environments occurred. Figure 7D displays the remnant ocean basin being consumed by subduction. The northward advancing subduction complex was being obducted onto the rifted continental margin of North America in early Atokan time (Houseknecht, 1986). Flexural bending soon became a main reason that caused the widespread normal faulting in the foreland of the southernmost part of North America's continental crust. Then subsidence and sedimentation increased. Abrupt thickness across the faults resulted from the deposition of middle Atoka sandstones and shales during the fault movement. Figure 7E shows how predominant thrusting became as the "subducting complex" kept moving northward against the opposing continental crust. Resultant uplift along the frontal thrust belt of the Ouachitas was the final stage of a peripheral foreland basin (Dickinson, 1974) in which shallow marine, deltaic, and fluvial sedimentation prevailed (Houseknecht, 1986) (Figure 8 and 9).

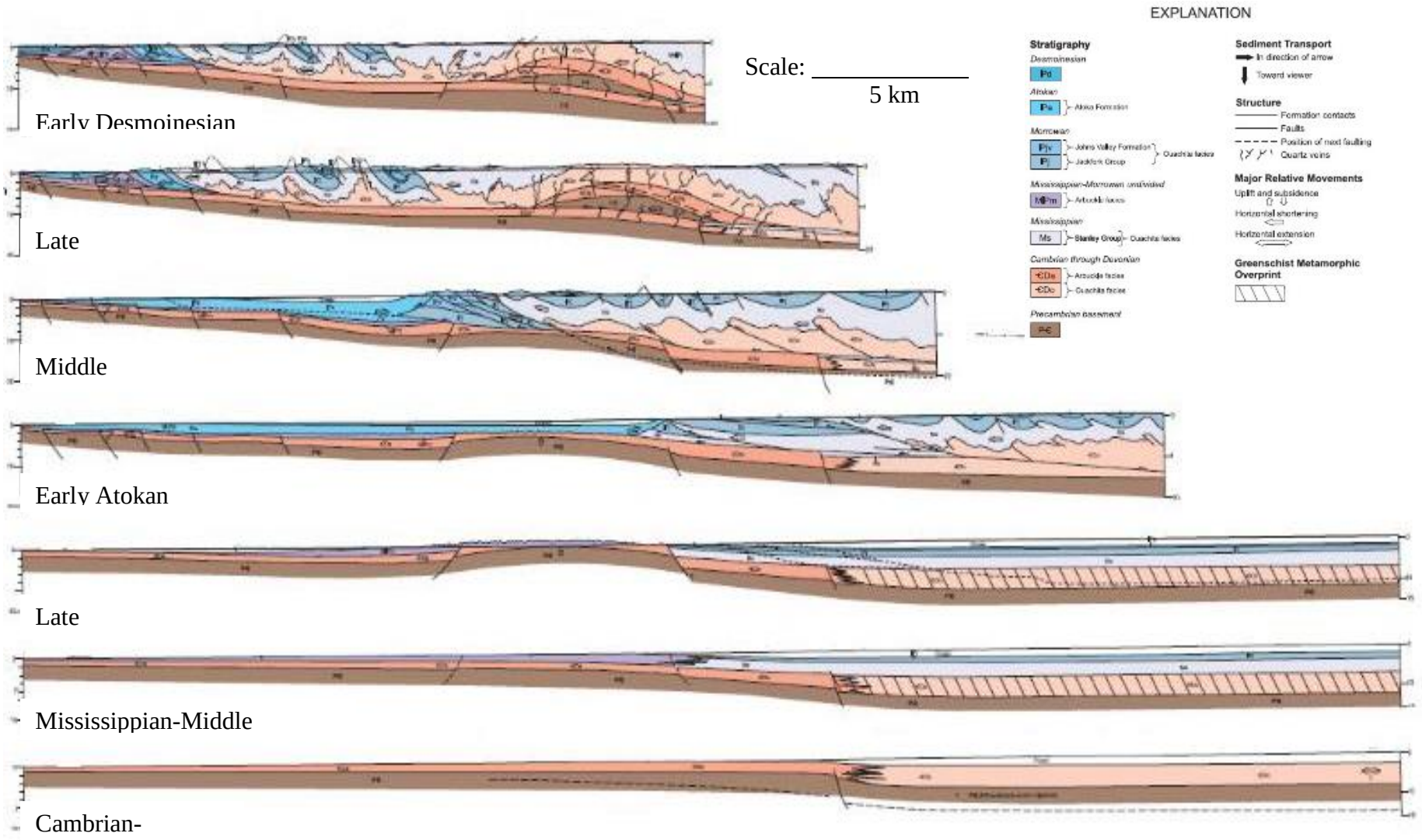

Figure 8: Sub-surface cross-sections showing evolution of the Arkoma Basin with the figures explanation (Houseknecht, 2009)

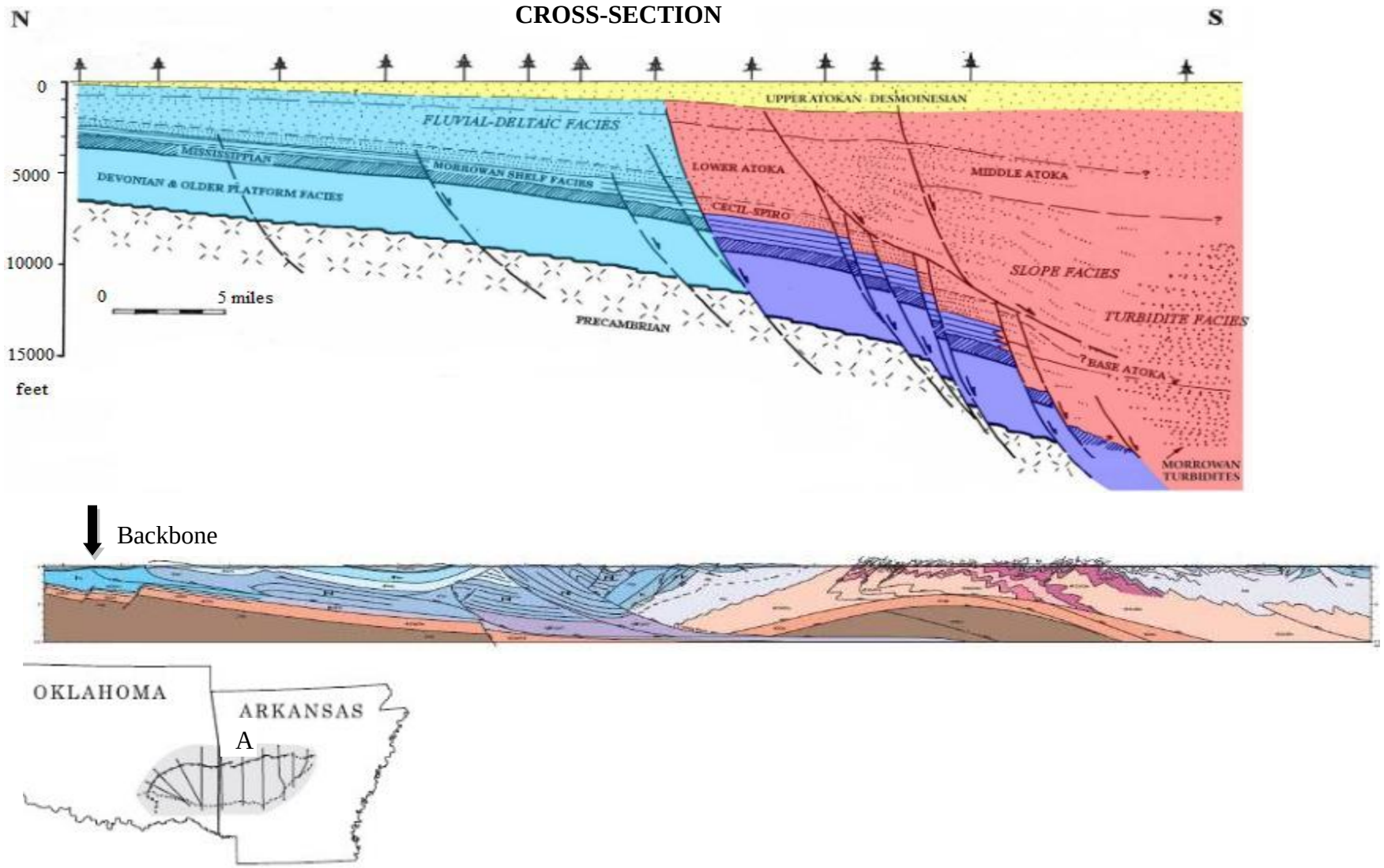

Figure 9: Two Sub-surface cross-section at A in the Arkoma basin showing location of Backbone anticline. Location of cross-sections is shown on map. Figure shows the Arkoma Shelf and the Arkoma-Ouachita Foredeep (Houseknecht et al., 2009).

III. STRATIGRAPHY

The Arkoma Basin contains gently to moderately deformed Pennsylvanian strata consisting of the Atoka Formation (Lower, Middle, Upper) and the Hartshorne Sandstone Formation. The Atoka Formation is the formation that will be considered in this study (Figure 10 and Table 1).

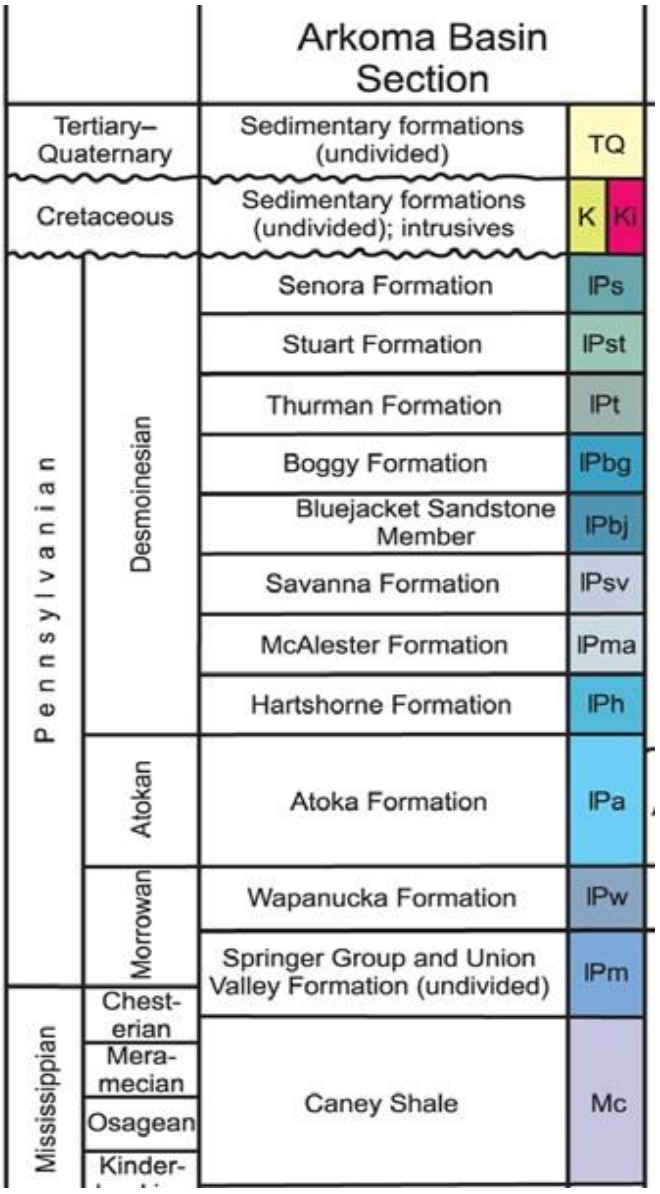

Figure 10: Stratigraphic Column showing specific units associated with the Arkoma Basin (Houseknecht et al., 2009).

Informal Nomenclature of Atoka Units

This Study	Other Commonly Used Names
Upper Carpenter	Carpenter, Carpenter A
Upper Alma *	
Middle Alma *	
Lower Alma *	
----------Base of Upper Atoka (Haley and Hendricks, 1972)----------	
Lower Carpenter *	Carpenter B
++++++++++Base of Upper Atoka (Zachry, 1983)++++++++++	
Glassy	
Morris *	Self, Tackett
Tackett *	Morris
Areci *	Self
Moyer	Hood, Upper Bynum
----------Base of Middle Atoka (Haley and Hendricks, 1972)----------	
Bynum[1]	
Hurst	Lower Bynum
Freiburg *	Henson, Pearson
Casey *	Hudson 1
Vernon	
++++++++++Base of Middle Atoka (Zachry, 1983)++++++++++	
Sells *	Dunn A, McGuire, Hudson 2
Upper Jenkins[2] *	Ralph Barton, Upper Alma, Jenkins
Lower Jenkins	Dunn B
Dunn C *	Dawson, Dawson A, Allen
Paul Barton	Dawson B, Russell, Lower Allen, Lower Dawson
Cecil Spiro *	Cecil, Hamm
Patterson	
Spiro *	Kelly, Orr, Barton, Basal Atoka, Greenland?

++++++++++

Zachry (1983) and Haley and Hendricks (1972) agree on the base of the Lower Atoka* - Names in bold-type are recognized basin-wide.

1 – In some cases the Bynum-Hurst interval may appear as a single sand, in which case the name "Bynum" is used.

2 – In some cases the Upper Jenkins-Lower Jenkins interval may appear as a single sand, in which case the name "Upper Jenkins" is used. (Table 1 is modified from Hacker, 2002)

Table 1: showing informal nomenclature of the Atoka units (modified by Hacker, 2002).

A. REGIONAL STRATIGRAPHY

The Arkoma Basin contains rocks of Cambrian to Pennsylvanian in age. In terms of thickness and areal extent, Atoka Formation dominates the basin's stratigraphic succession. The Atoka consists of Pennsylvanian rocks and is divided into lower, middle, and upper units based on their depositional features. The Lower Atoka consists of multiple sandstone units separated by intervals of shales. Multiple normal faults disrupt the beds. Reverse faults are rare because the lower units are part of an extensional deposition system. There is not any thrust faults located in the Lower Atoka in the study area. It consists of primarily normal faults (horst and graben structures). The Middle Atoka in Arkansas is composed predominately of shale, with laterally discontinuous sandstone units within the succession (Zachry and Sutherland, 1984). It displays increasing thickness toward the south. The Upper Atoka is not as thick as the Middle Atoka. The Upper Atoka consists of sandstone units with thick intervals of shales. Both the Middle and the Upper Atoka were in a compressional deposition environment, so reverse/thrusts faults would be most likely to occur more often in these two units. The rocks in the Arkoma Basin vary in thickness, thin at the northern margin adjacent to the platform (1000 ft), to over 23,000 ft of thickness adjacent to the orogenic belt in frontal zone of the Ouachita Mountains (Zachry, 1983). The Middle Atoka displays the greatest amount of thickness (about 30,000 ft) in the Ouachitas.

B. LOCAL STRATIGRAPHY

The Upper Alma to the Turner units and the Turner to the Dunn units in the study are grouped together, in as much as these specific units are difficult to characterize and distinguish. The Upper Alma to the Turner sections consists of interbedded shales and sandstones with increasing deltaic sands. The Turner to the Dunn predominately consists of sandstones with a few shales.

Some of these sandstones consist of well-defined coarsening-upward sequences. The sandstone units vary in thickness from tens to 350 feet. Shales units are interbedded in the sandstone units and vary in thicknesses, they exceed thicknesses of about 600 feet (Figure 11).

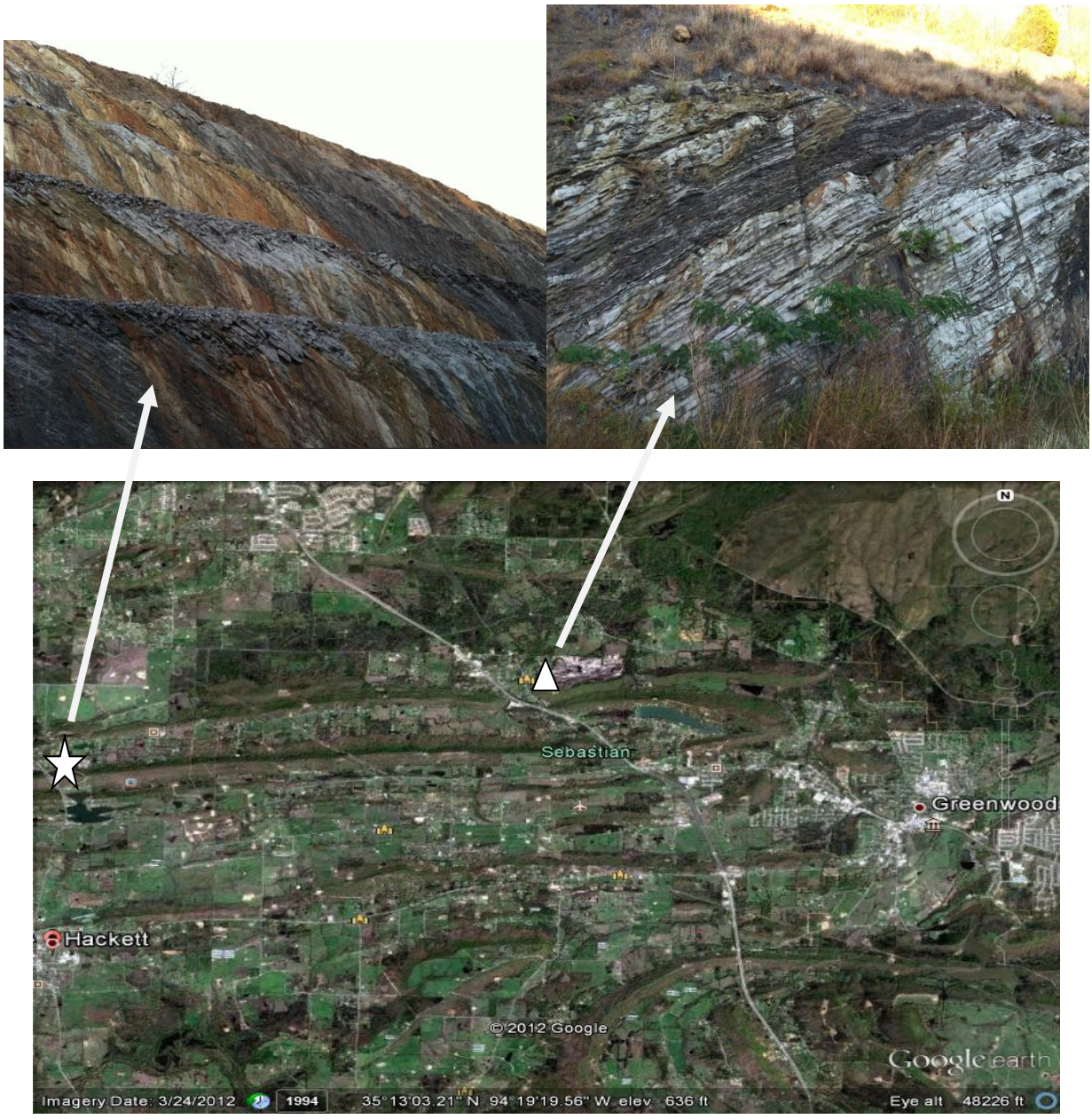

Figure 11: pictures taken by author at two different roadcuts shown on map in study area showing the Atoka Formation (interbedded shales and sandstones). Picture right shown on map (taken from Google Earth) by the triangle and picture left (illustrating the southern dipping strata) shown on map by the star.

Atoka Formation

The Atoka Formation is within of the Pennsylvanian System and is divided into three parts (Lower, Middle and Upper). The Atoka contains mostly of shale, siltstone, and sandstone. The Atoka Formation consists of dark-gray to grayish-black shale, dark-gray slightly silty to very silty shale, medium to dark-gray siltstone, light to dark-gray very fine grained sandy siltstone, light to medium-gray slightly silty to very fine- to fine-grained sandstone, some light to medium grained sandstone, and, in the upper part, a few coal beds. Sandstones are quartzose in part and argillaceous in part. Pyrite is a common accessory mineral and iron-rich concretions and fossil plant fragments are scattered throughout the Formation. Siltstones are highly micaceous. The bedding in the exposed sandstone in the Atoka Formation is extremely variable. It may be lenticular, irregular, or regular, and very thin to massive. The sandstone is cross-bedded and have fore set beds and contains convolute bedding. Invertebrate fossils are rare in the Atoka and topographically the Atoka normally is a valley and slope former in the region (Baker, 2009).

Hartshorne Sandstone

The Hartshorne Sandstone (along with the McAlester and the Savanna Formations) lies on and under the surface of the Backbone Anticline. It consists of grayish-white to light gray very fine to medium-grained sandstone containing very few thin beds and lenses of dark-gray shale, silty shale and siltstone. Individual beds of sandstone in the Hartshorne are regular, irregular, or lenticular. They may be cross-bedded, or have convolute bedding. It is one of the most persistent sandstone units in Arkansas. The unit is one of the prominent ridge formers of the ridges and mountains of the Arkansas River Valley (including in the Arkoma Basin). As a sandstone unit, it has several lithologic characteristics which tend to set it apart from most of the sandstone units in the overlying McAlester Formation or in the underlying Atoka Formation. In general, the

Hartshorne Sandstone is lighter in color (grayish-white to light gray), coarser in grain size (very fine to medium), less silty or clayey, and more widespread. Fossilized plants, usually pieces of roots, trunks, or branches commonly occur in the Hartshorne and are more numerous in the upper part of the formation (Baker, 2009).

IV. FAULT NOMENCLATURE

Two main kinds of faults that were observed in this study: normal and thrust faults. Normal Faults typically produce conjugate fault systems as they do not traditionally exist alone. The faults in such a fault system tend to display parallel strike (Ouachita Thrust Belt), but diversified levels of vertical displacement. Generally, the faults in such a setting exhibit opposing dips creating a horst and graben structure (Welcome, 2011) (Figure 12). They usually are created in an extensional structure environment. In the area of study, this is located on the northern edge of the Arkoma Basin and south of the Ouachita thrust belt.

Thrust faults are reverse faults however they dip at a lower angle. Reverse faults/ thrust faults are where the hanging wall moves up relative to the foot wall which moves down. Normal faults are the opposite, where the hanging wall moves down relative to the foot wall. Thrust/reverse faults generally occur in compressional structured environments.

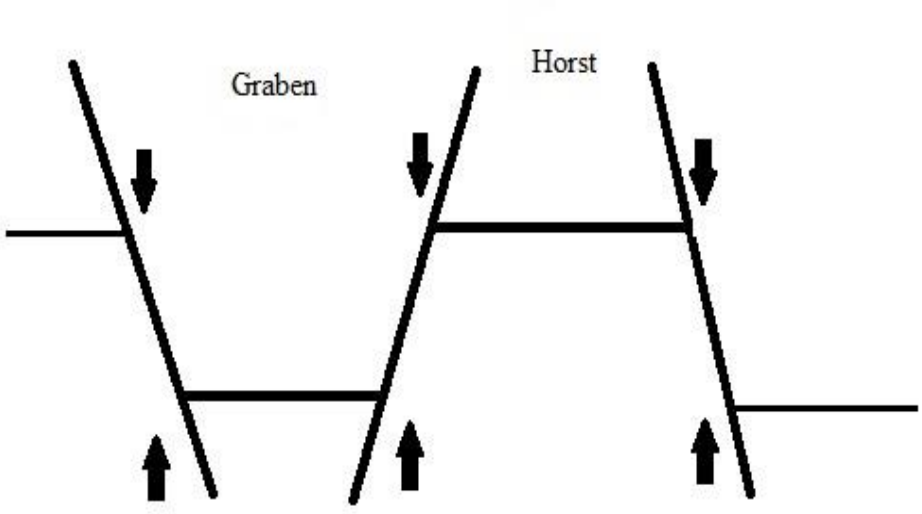

Figure 12: example of the horst and graben structure (made by author).

V. METHODS

A. WIRELINE WELL LOGS

Wire line well logs were obtained and were a crucial part of the study. IHS Petra software was used. Within the Petra software, the wire line logs were imported from the IHS US Enerdeq database. Some wells did not have raster logs, so they were obtained from the Arkansas Oil and Gas Commission and were depth registered into Petra. Maps were created with layers that showed the wells that were in my area of study (Figure 13). From these maps, well-to-well cross-sections were created.

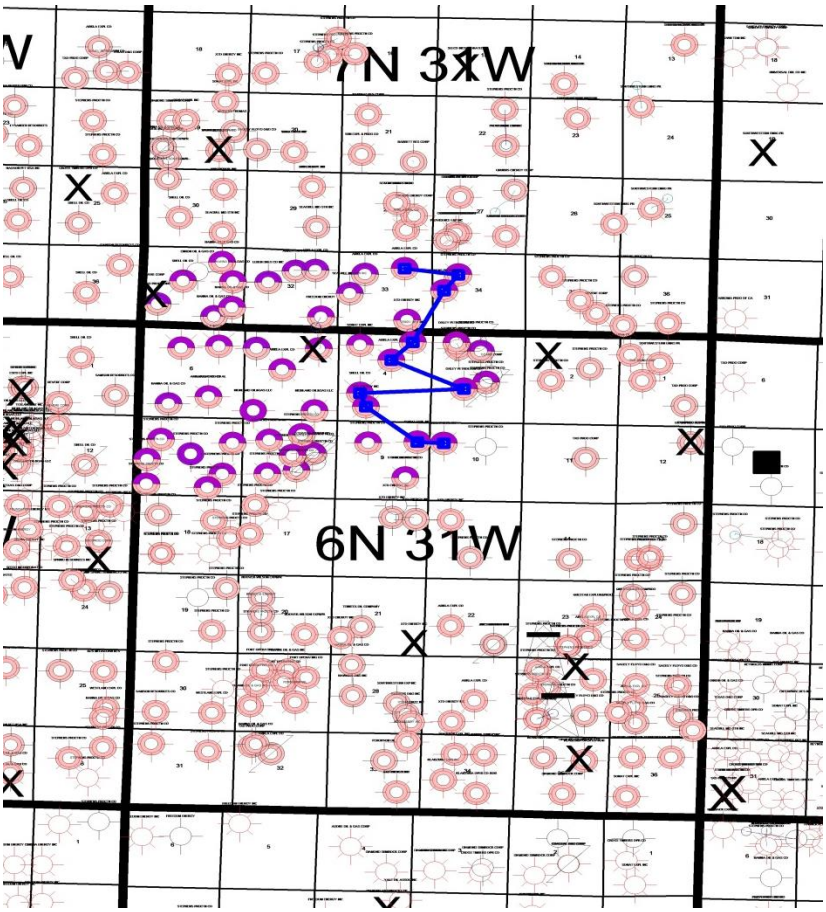

Figure 13: Map used to created well-to-well cross-sections in Petra. This example has the north to south well-to-well cross-section that is located on the east side of the area of study. The circles represent drilled wells and the half pink, half purple circles represents the drilled wells included in study.

B. CROSS-SECTIONS

Seven cross-sections were created (west-east in the center of study area, north-south center, north-south western portion, north-south eastern portion, north-south eastern portion with more wells, west-east northern portion of study area, and west-east southern portion of study area). Each cross-section was correlated by observing the well to well cross-sections and finding the tops in each well that correlate with each other and connecting those tops. Then by researching the kind of rocks found in each named unit and the well logs themselves, the picked tops in this study were named (Figure 14 and 15). From the correlations, tops of the main units in the sub-surface were easily visible. Each was studied closely to see any thrust faults in the area that was affecting the Backbone anticline within the certain study area. Three cross-sections were more focused (north-south western portion of study area, north-south eastern portion of study area, and the west-east in the center of study area). The others are in Appendix I as they didn't contribute to the investigation.

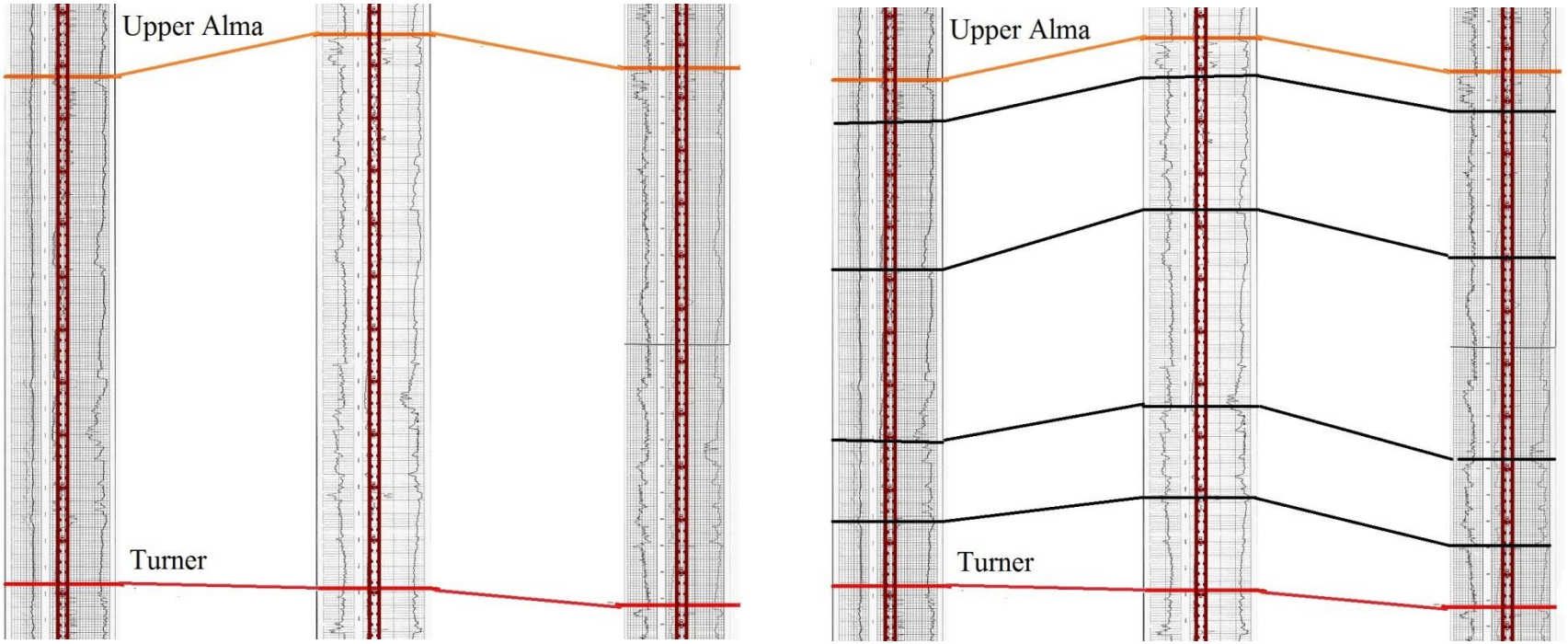

Figure 14: Illustrating how to correlate well-to-well cross-sections (taken from cross-section B-B'). Second well log shows an example of increasing deltaic sands closer to the top of the Turner (made by author).

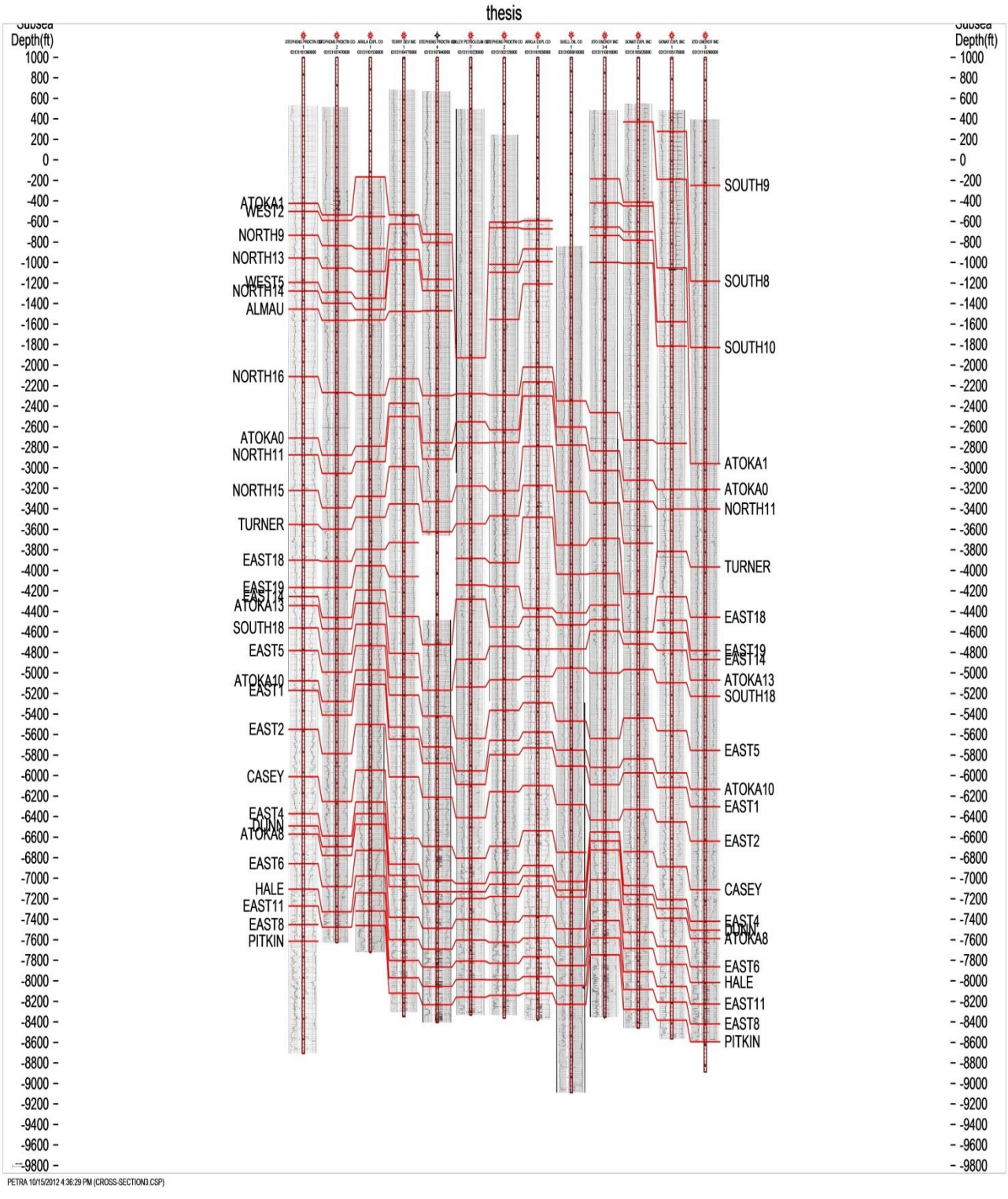

Figure 15: example of a correlated cross-section taken from Petra. This example goes with the map above (figure 13 on page 20), so it too is located on the east side of the study area (north to south).

VI. DISCUSSION

All three cross-sections (A-A', B-B', C-C') show evidence for numbers of deltaic sands in between the Turner and Upper Alma units. They also show normal faults below the top of the Turner but not cutting past the top of the Turner. There are also horst and graben structures in each cross-section. The Casey, Dunn, Hale, and Pitkin unit are associated to the early Middle Atokan. The Turner unit lies in the later Middle Atokan period and the Alma in the Later Atokan period. So the reason behind to the normal faults stopping below the Turner unit and not passing into the late Atokan falls to the evolution of the Arkoma Basin in the Middle Atoka. As a result of the widespread normal faulting caused by flexural bending in the early Atokan, subsidence and sedimentation was occurring in the middle Atokan. Throughout this fault movement, there was deposition of the Atokan sandstones and shales, which caused an abrupt thickness change across the faults (in this case, above the Turner unit and below the Upper Alma. This also was the turning point between the normal faulting and the occurring thrust faulting in the Arkoma Basin (Late Atokan). The Casey unit and other units below the Casey correlated very well and displayed numerous normal faults including horst and graben structures. However, above the Casey, was not as homogenous and didn't correlate as well. It displayed multiple areas with increased thicknesses and displacements. So, the reverse fault must run above the Casey and thrusts upward through the Turner unit and up past the Upper Alma unit thrusting up to the surface displaying at the crest of the Backbone anticline.

Cross-section A-A'

Cross-Section A-A' is oriented north to south in 7N 31W to 6N 31W on the western portion of the study area. Wells 5,6, and 7 from the left (south-central of field study) on the cross-section

shows an increase in thickness between the Upper Alma and the Turner. It shows evidence of increasing deltaic sands in this area. Below the Turner are very noticeable normal faults. However, following them to shallower depth it seems as if the normal faults do not displace the top of the Turner. The normal faults display a horst and graben structure in the deeper depths (involving units Casey, Dunn, Hale, and the Pitkin) (Figure 16).

Cross-section B-B':

Cross-Section B-B' is a north to south cross-section in 7N 31W to 6N 31W on the eastern portion of the study area. The well 6, 7, 8, and 9 from the left on the cross-section also shows an increase in thickness in depths between the Upper Alma and the Turner. It has evidence of increasing deltaic sands in this area. Normal faults has been interpreted to also cut through the tops of the Pitkin, Hale, Dunn, and the Casey in this area, however, that they terminate below the top of the Turner, and do not displace the Alma unit. There is one horst and graben structure depicted in the section at deeper depths (Figure 17).

Cross-section C-C':

Cross-Section C-C' is a west to east cross-section in 6N 31W near the center of the study area. Wells 1, 2, and 3 from the left on the cross-section also shows an increase in thickness in depths between the Upper Alma and the Turner. At the eastern-most well , there is evidence of increasing deltaic sands in this area and has an increase of thickness between the Upper Alma and Turner tops. So, increasing deltaic sands start again at this section between the two units. Normal faults are interpreted to be cutting through the tops of the Pitkin, Hale, Dunn, and the Casey but not the Turner. There is one horst and graben structure depicted at depth (Figure 18).

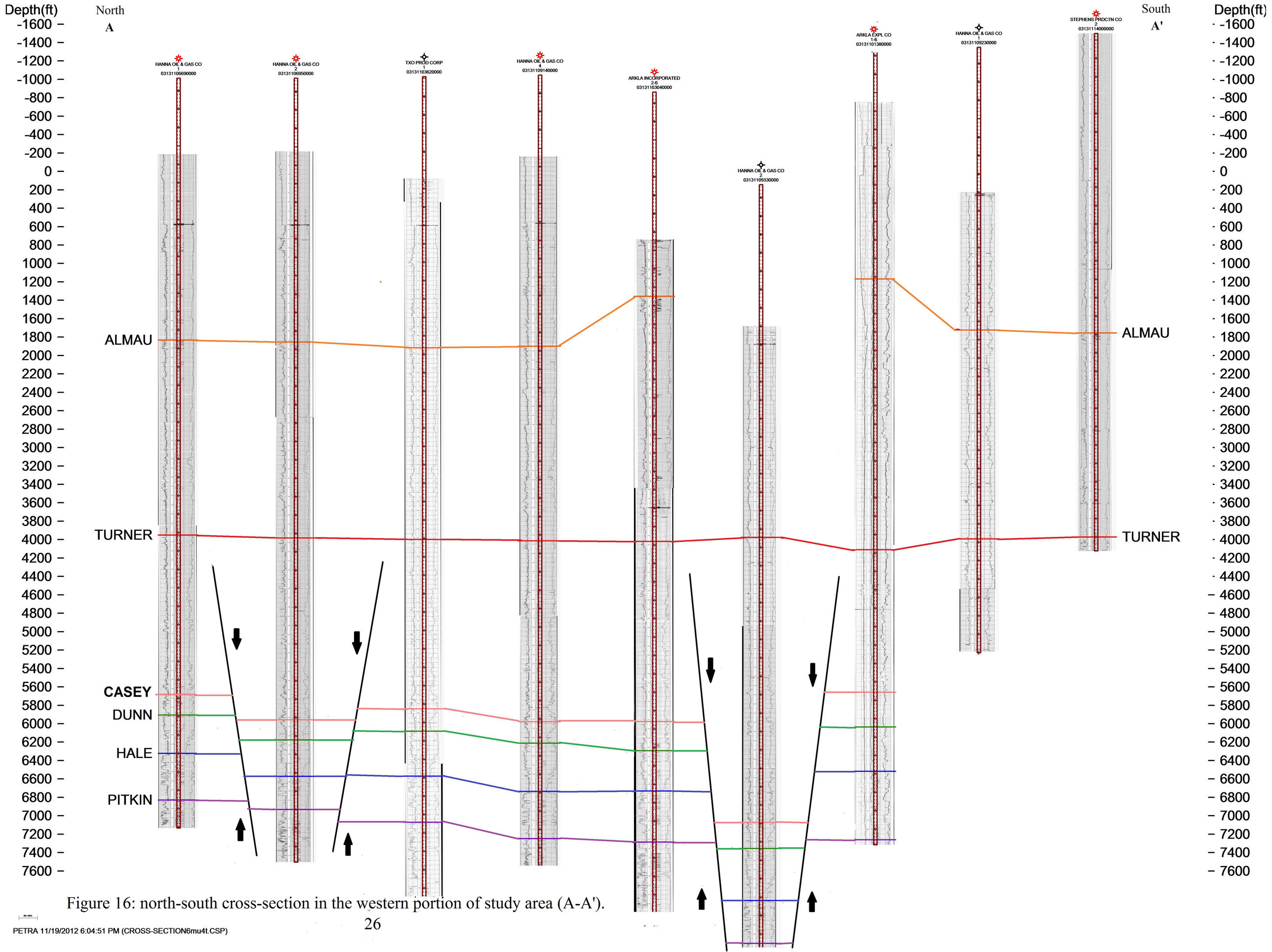

Figure 16: north-south cross-section in the western portion of study area (A-A').

PETRA 11/19/2012 6:04:51 PM (CROSS-SECTION6mu4t.CSP)

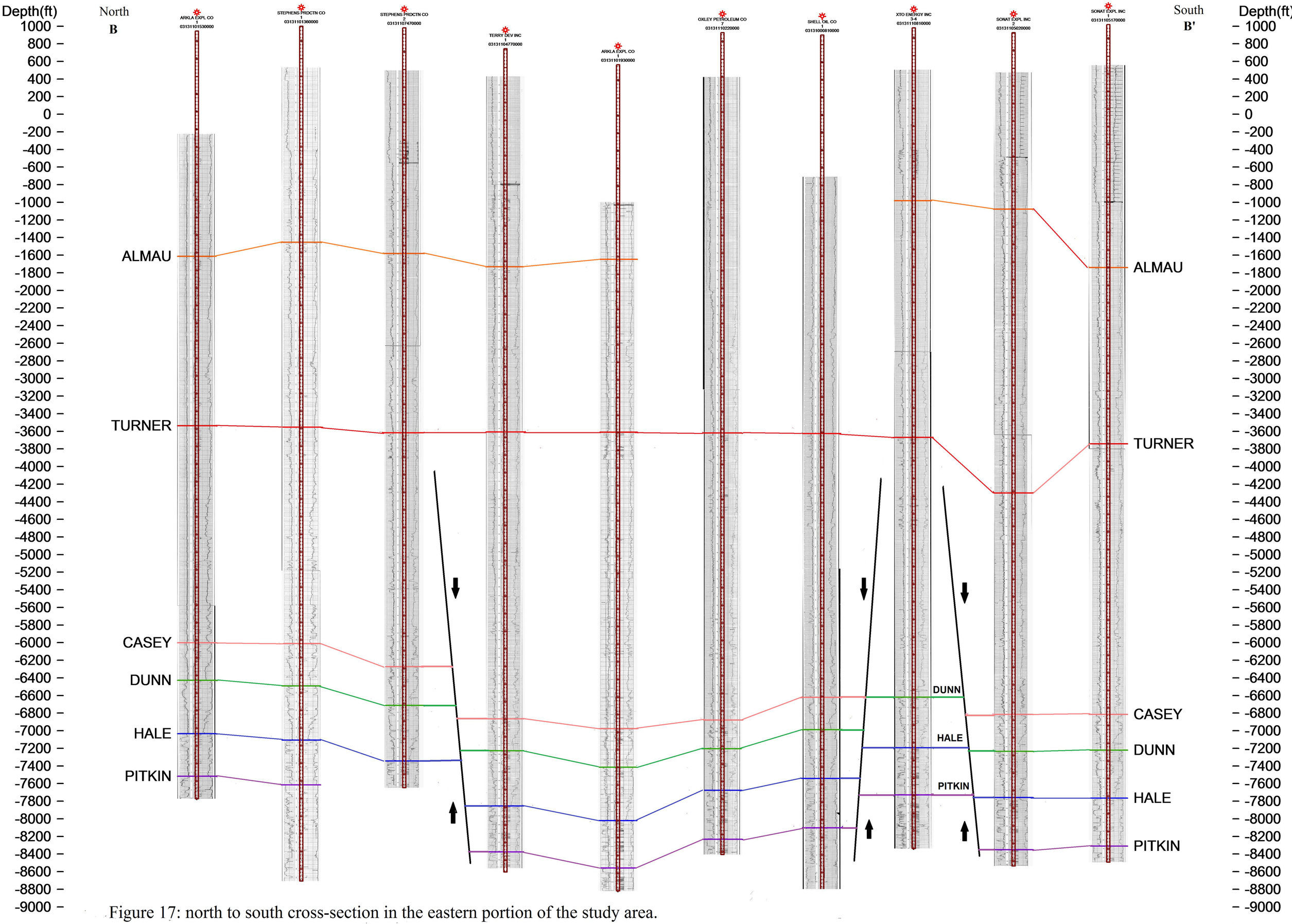

Figure 17: north to south cross-section in the eastern portion of the study area.

PETRA 11/19/2012 6:02:45 PM (CROSS-SECTION3mu4t.CSP)

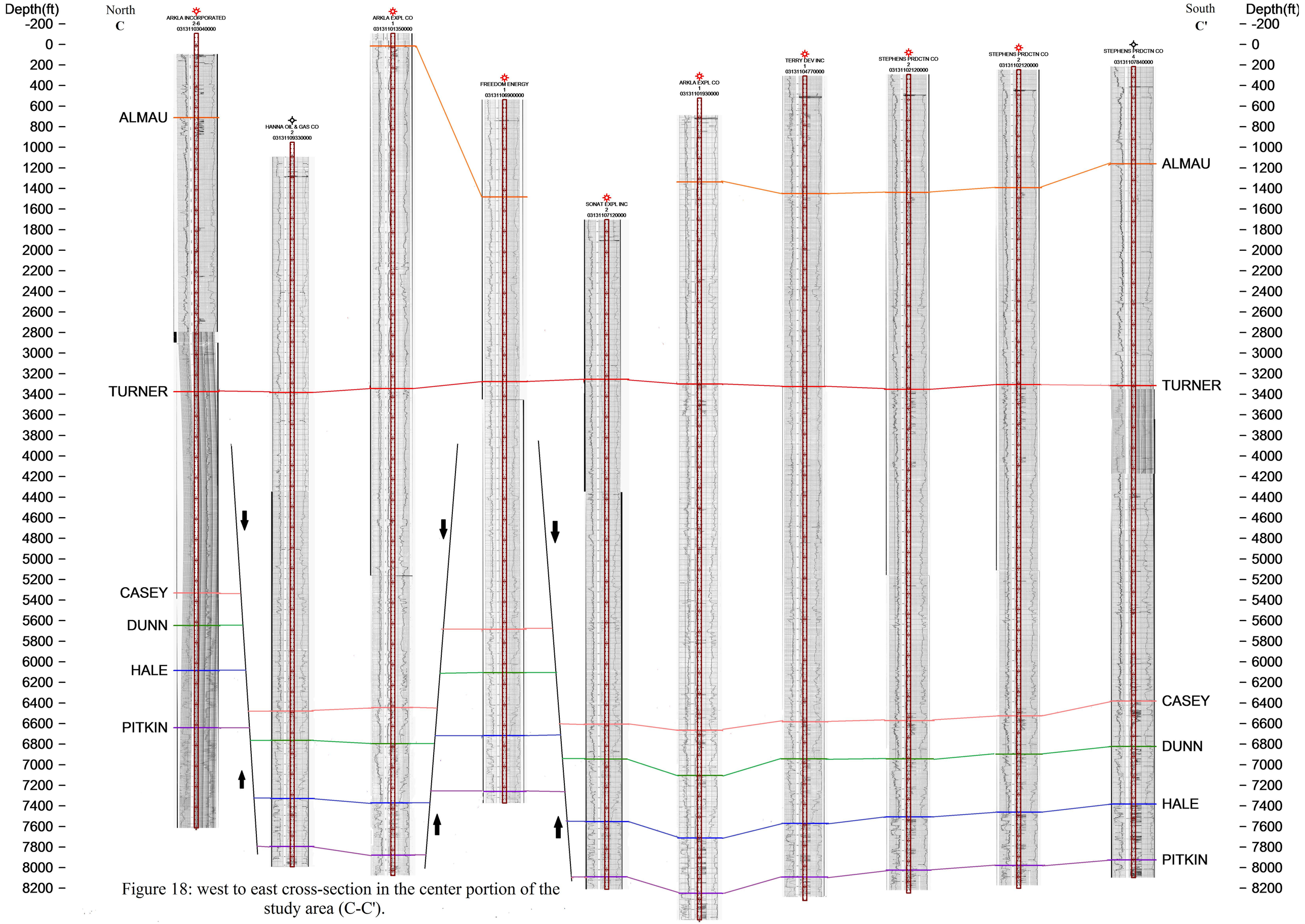

Figure 18: west to east cross-section in the center portion of the study area (C-C').

PETRA 11/19/2012 6:00:39 PM

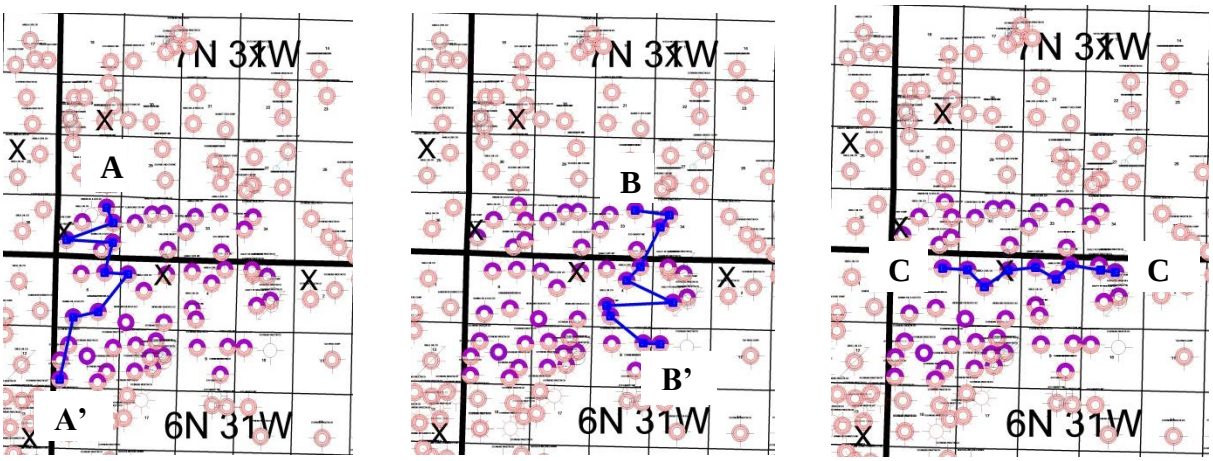

Figure 19: Maps associated with cross-sections A-A', B-B', and C-C' from Petra.

VII. CONCLUSION

In conclusion, the Backbone anticline is one of several anticlines located north of the Ouachita orogenic belt in the Arkoma Basin. Listric thrust faults underlie much of the folded section and ramp to the surface along the crests of many anticlines (Houseknecht, 1986). All three cross-sections (A-A', B-B', C-C') show evidence for increasing thicknesses and deltaic sands between the Turner and Upper Alma units. They also show normal faults below the top of the Turner but not cutting past the top of the Turner. There are also evidence horst and graben structures in each cross-section. However, there wasn't any evidence on the correlated cross-sections that depicted thrust faults in this study area of the Backbone anticline. The Backbone anticline though does have a thrust fault driving through the crest (the field of study may lie too much north from the main thrust fault to show evidence in the study). The Casey and below units correlated very well and displayed numerous normal faults displaying horst and graben structures. However, above the Casey, was not as homogenous and didn't correlate as well. It displayed multiple areas with

increased thicknesses and displacements. So, if a thrust/reverse fault is in the area of study, it must run above the Casey and thrusts upward through the Turner unit and up past the Upper Alma unit thrusting up to the surface displaying at the crest of the Backbone anticline (Figure 20).

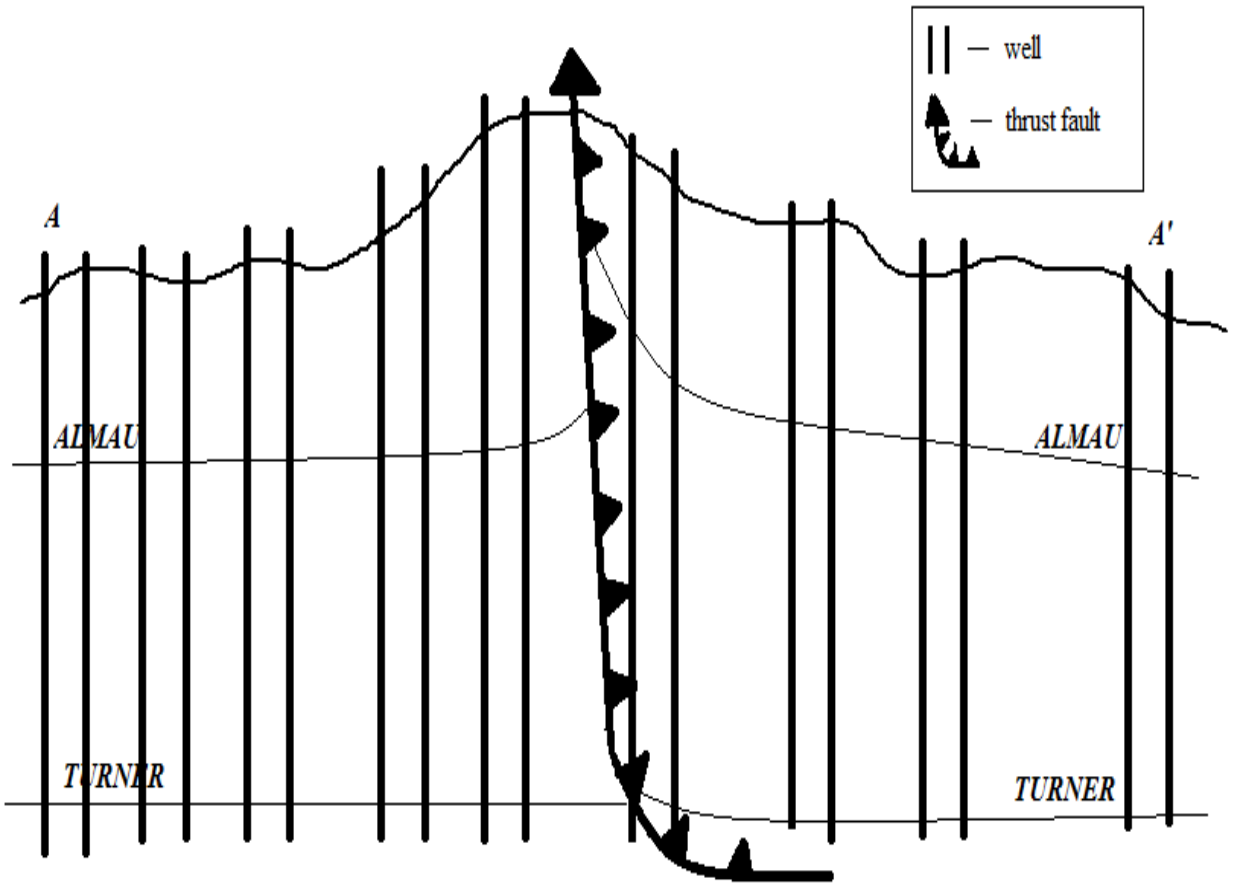

Figure 20: Picture representing thrust fault position above Lower Atoka strata. Fault is stratigraphically above most of the Lower Atoka (made by author).

VIII. REFERENCES

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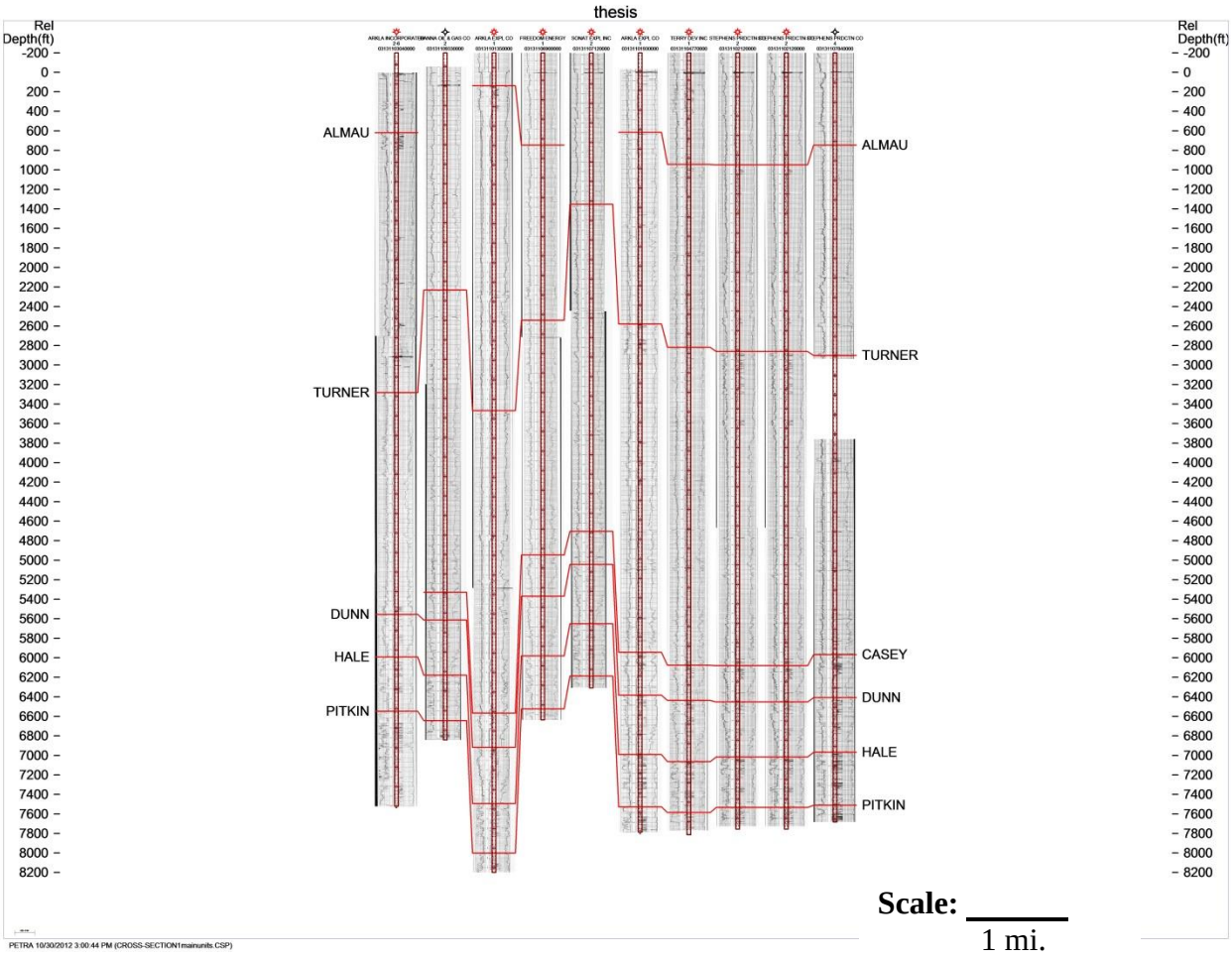
VIIII. APPENDIX I:
Correlated Cross-Sections with Maps



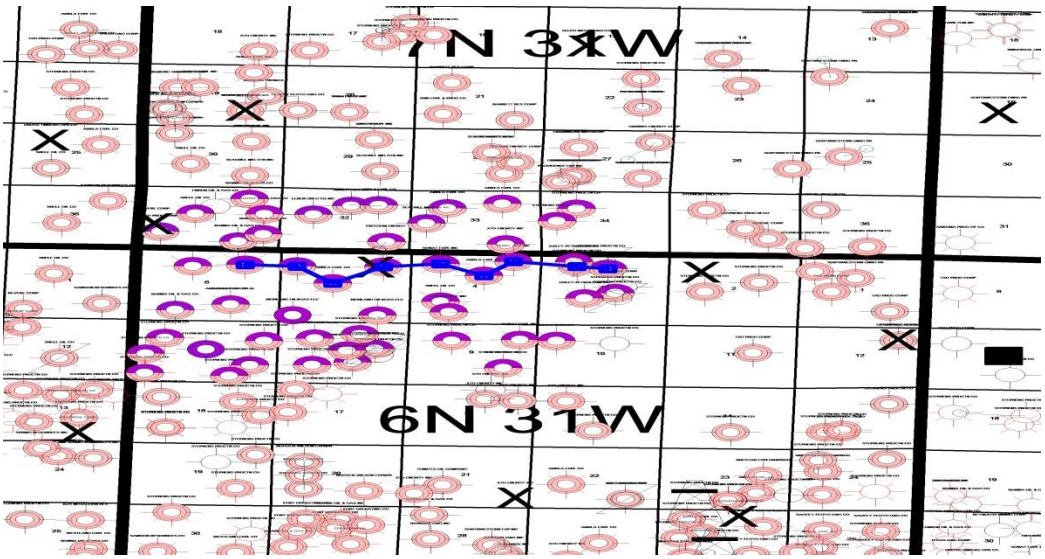


Figure 21: West-East structure cross-section in the Backbone anticline center portion of study area.

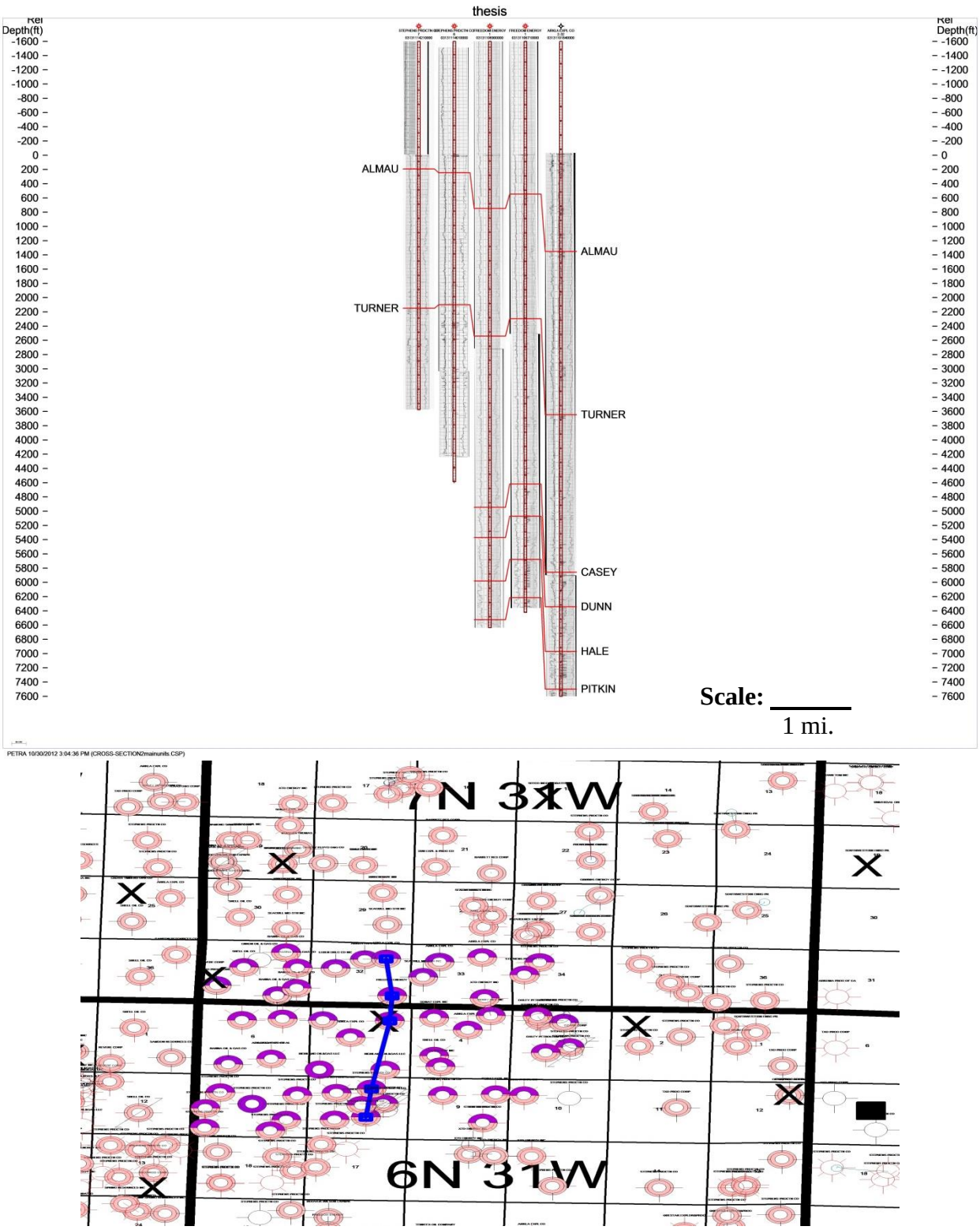


Figure 22: North-South structure cross-section in the Backbone anticline in center portion of study area.

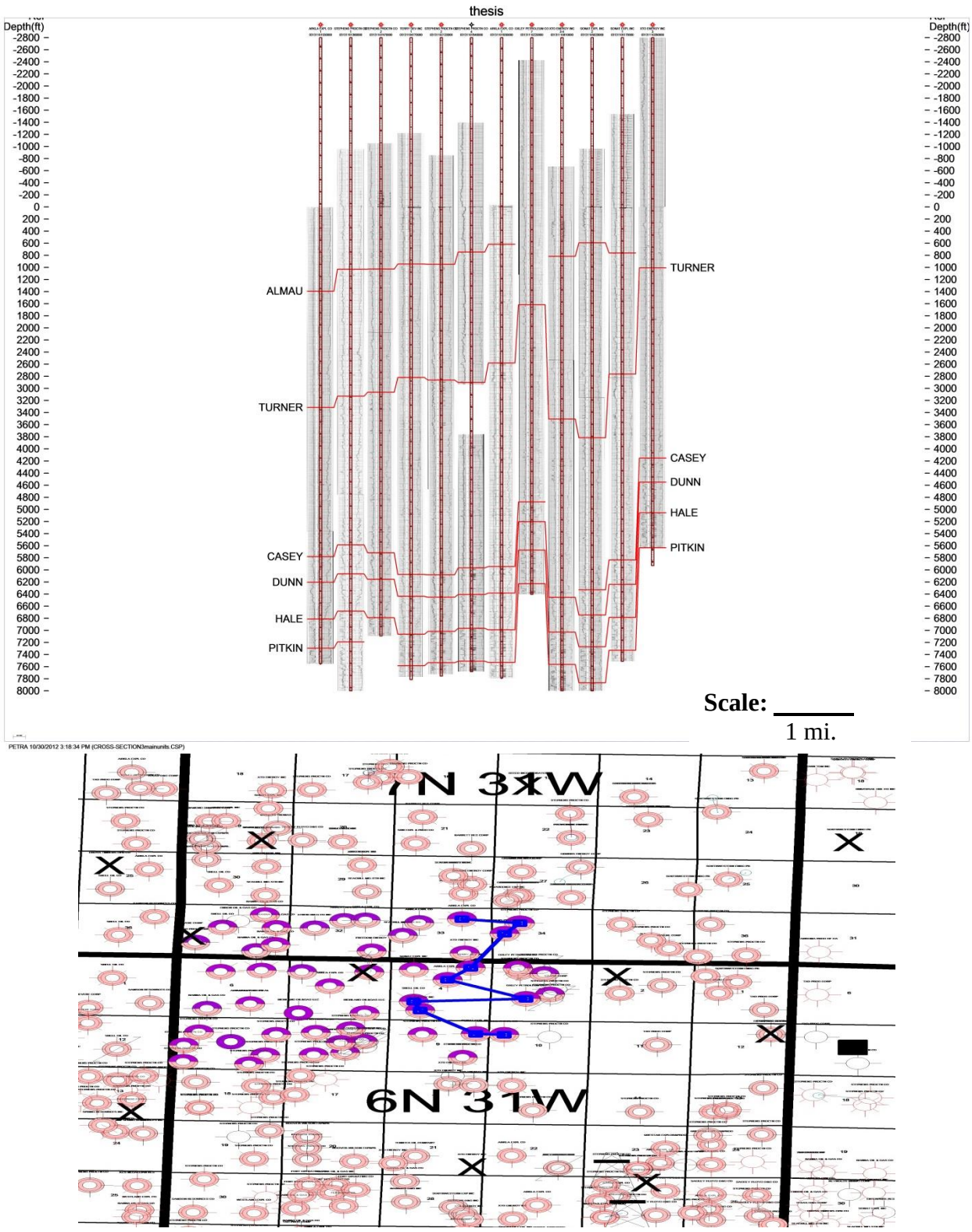


Figure 23: North-South structure cross-section in the Backbone anticline in eastern portion of study area (includes more wells than the cross-section in Figure 19).

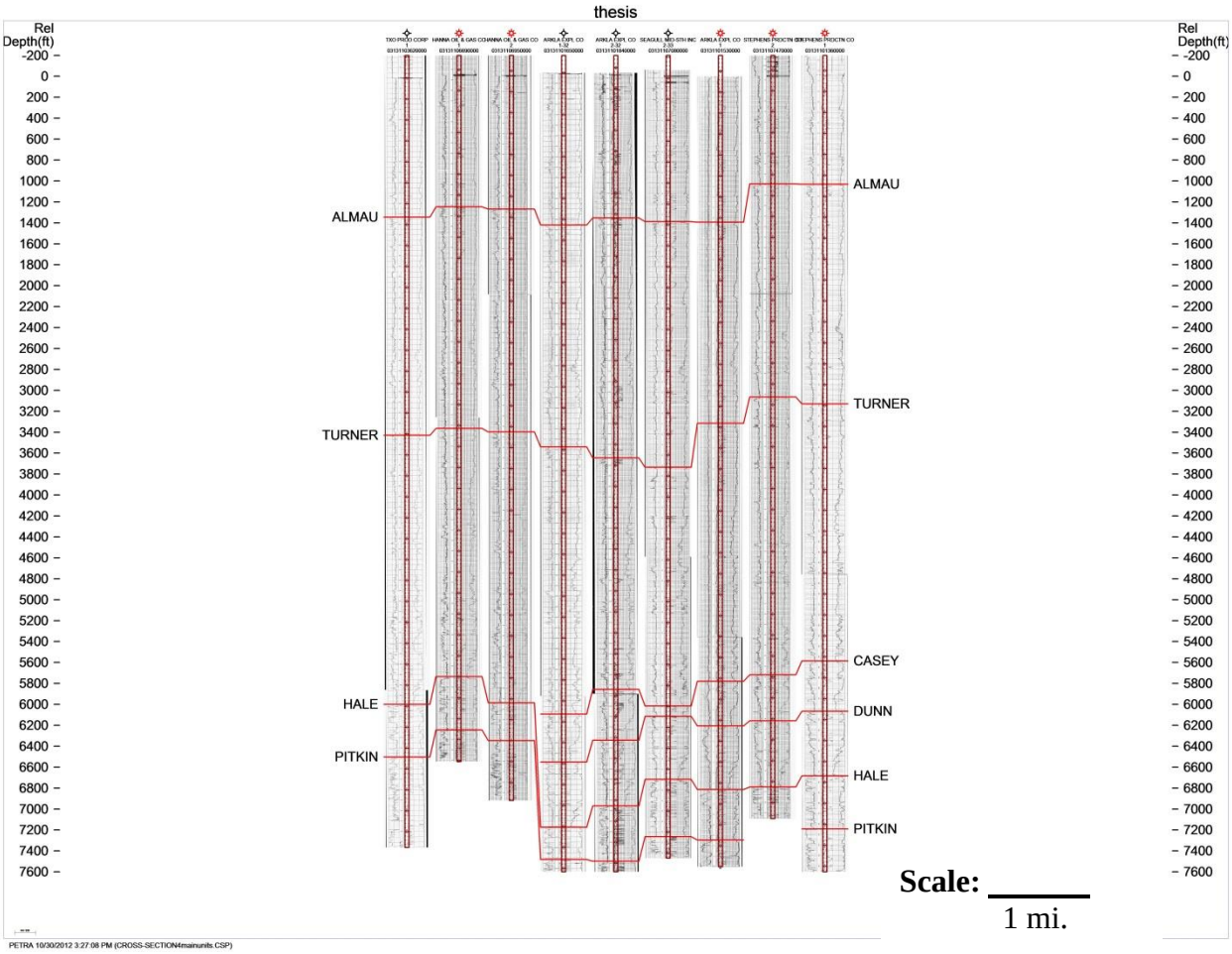


Figure 24: West-East structure cross-section in the Backbone anticline in northern portion of study area.

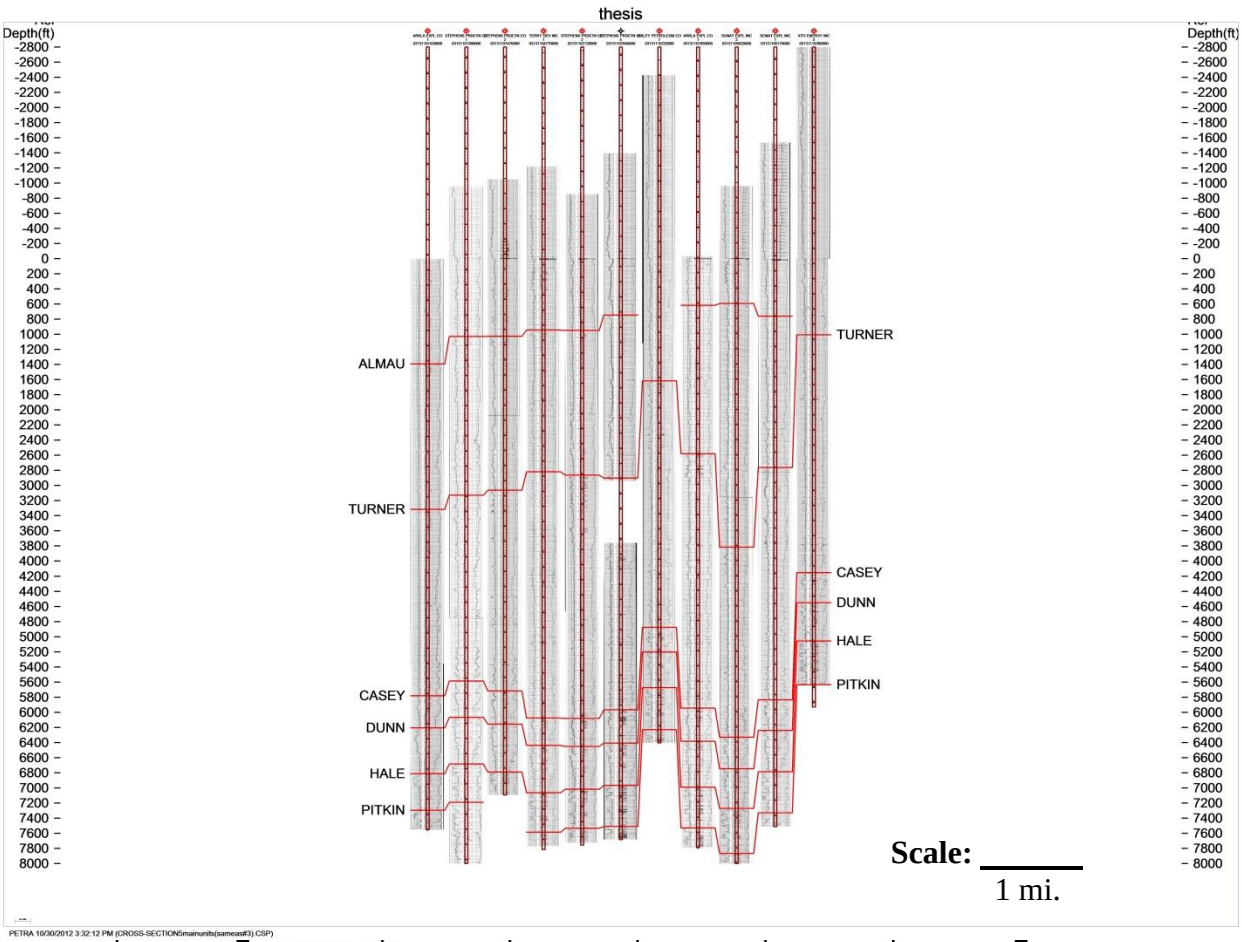


Figure 25: North-South structure cross-section in the Backbone anticline in eastern portion of study area.

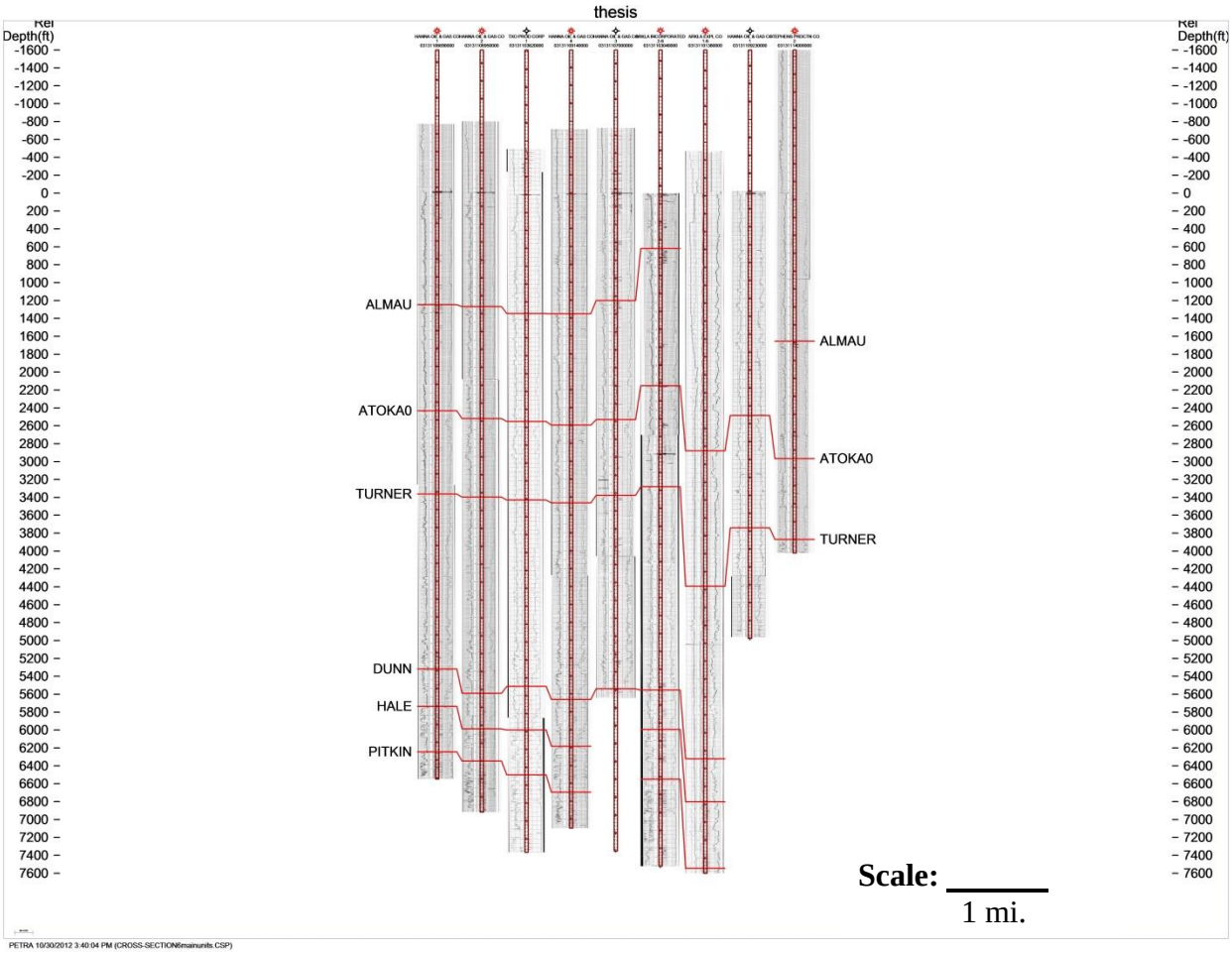


Figure 26: North-South structure cross-section in the Backbone anticline in western portion of study area.

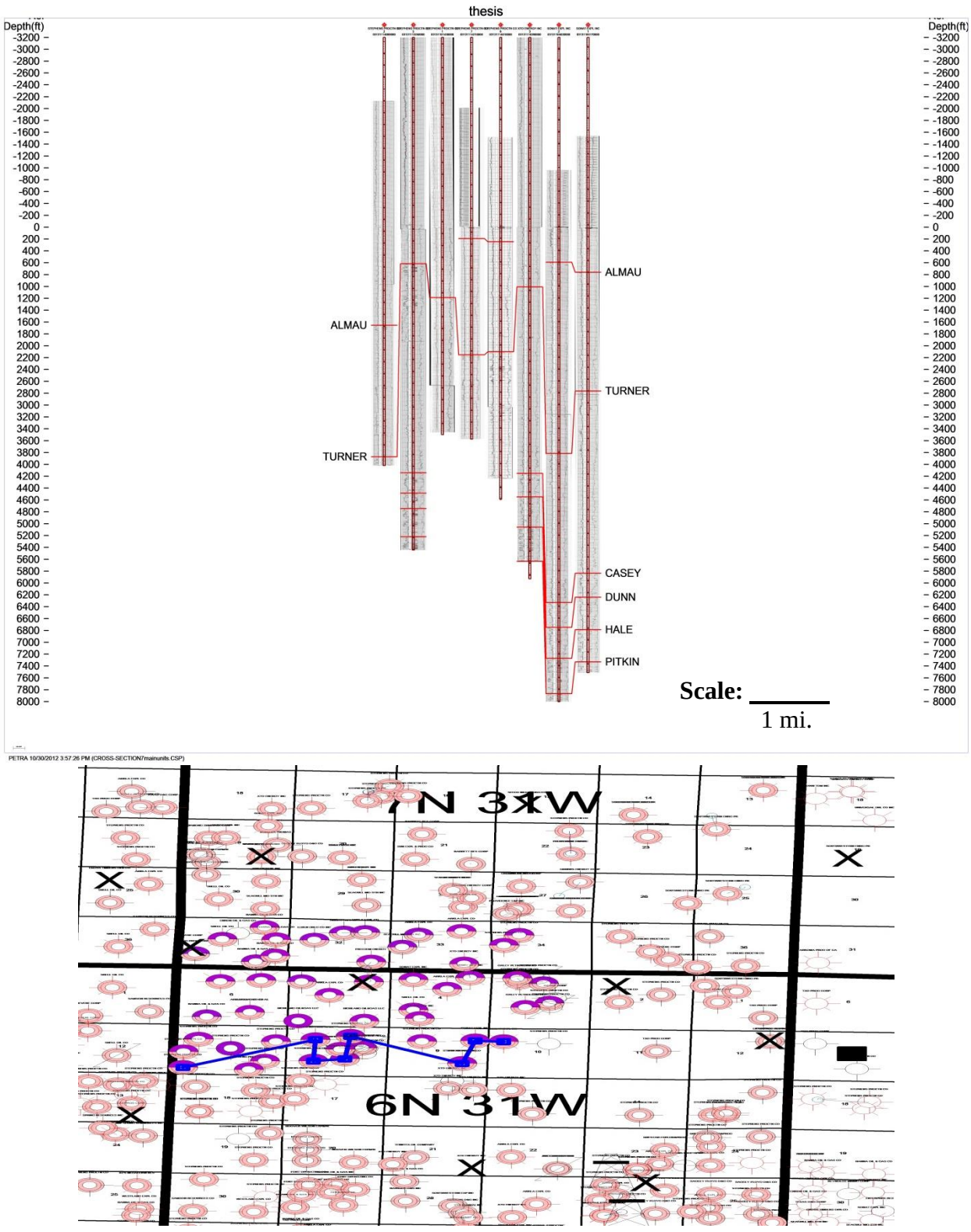


Figure 27: West-East structure cross-section in the Backbone anticline in southern portion of study area.

X. APPENDIX II:
Wells Used in Study

UWI or API #	WELL #	OPERATOR	LABEL	TOWNSHIP	RANGE	SECTION
3131106690000	1	Hanna Oil & Gas CO	Hanna Oil & Gas CO 1-Prairie Creek	7N	31W	31
3131000040000	3	Shell Oil CO	Shell Oil CO 3-Western Coal & Mng	7N	31W	31
3131106950000	2	Hanna Oil & Gas CO	Hanna Oil & Gas CO 1-Prairie Creek	7N	31W	31
3131103620000	1	TXO Prod CORP	TXO Prod CORP-Cooper Bill	7N	31W	31
3131109140000	4	Hanna Oil & Gas CO	Hanna Oil & Gas CO 1-Prairie Creek	7N	31W	31
3131107000000	3	Hanna Oil & Gas CO	Hanna Oil & Gas CO 1-Prairie Creek	7N	31W	31
3131101840000	2_32	ARKLA EXPL CO	ARKLA EXPLO CO 2-32- Missouri Improvemnt	7N	31W	32
3131101650000	1_32	ARKLA EXPL CO	ARKLA EXPLO CO 1-32- Missouri Improvemnt	7N	31W	32
3131100150000	1	Leben DRLG CO INC	Leben DRLG CO INC 1-Missouri Improvemnt	7N	31W	32
3131106710000	1	Freedom Energy	Freedom Energy 1-Brooks	7N	31W	32
3131101530000	1	ARKLA EXPL CO	ARKLA EXPLO CO 1- Missouri Improvemnt	7N	31W	33
3131101210000	1_33	ARKLA EXPL CO	ARKLA EXPLO CO 1-33-Wolfe	7N	31W	33
3131107080000	2_33	Seagull Mid-Sth INC	Seagull Mid-Sth INC 2-33-Missouri Improvement	7N	31W	33
3131110200000	3_33	XTO Energy INC	XTO Energy INC	7N	31W	33

			3-33-Missouri Imp.			
3131101360000	1	Stephens Prdctn CO	Stephens Prdctn CO 1-Nelch	7N	31W	34
3131107470000	2	Stephens Prdctn CO	Stephens Prdctn CO 2-Nelch	7N	31W	34
3131103040000	2_6	ARKLA INCORPORATED	ARKLA INCORPORATED 2-6-Holleman	6N	31W	6
3131000780000	1	Shell Oil CO	Shell Oil CO 1-Edwards	6N	31W	6
3131101380000	1_6	ARKLA EXPL CO	ARKLA EXPLO CO 1-6-McNabb	6N	31W	6
3131109230000	1	Hanna Oil & Gas CO	Hanna Oil & Gas CO 1-Sturgeon Road	6N	31W	6
3131109330000	2	Hanna Oil & Gas CO	Hanna Oil & Gas CO 2-Lind Jenny	6N	31W	5
3131106900000	1	Freedom Energy	Freedom Energy 1-Lind Jenny	6N	31W	5
3131101350000	1	ARKLA EXPL CO	ARKLA EXPLO CO 1- Holleman	6N	31W	5
3131114480000	3_5D	Highland Oil&Gas LLC	Highland Oil&Gas LLC 3-5D-Lind Jenny	6N	31W	5
3131104770000	1	Terry DEV INC	Terry DEV INC 1-Farmers Bank	6N	31W	4
3131107120000	2	Sonat EXPLO INC	Sonat EXPLO INC 2-Farmers Bank	6N	31W	4
3131101930000	1	ARKLA EXPLO CO	ARKLA EXPLO CO 1-Kersey	6N	31W	4
3131000810000	1	Shell Oil CO	Shell Oil CO 1-Skinner	6N	31W	4
3131110810000	3_4	XTO Energy INC	XTO Energy INC 3-4-Farmers Bank	6N	31W	4

3131110060000	6	Oxley Petroleum CO	Oxley Petroleum CO 6-Walker Ruth	6N	31W	3
3131102120000	2	Stephens Prdctn CO	Stephens Prdctn CO 2-Walker Ruth	6N	31W	3
3131107840000	4	Stephens Prdctn CO	Stephens Prdctn CO 4-Walker Ruth	6N	31W	3
3131100090000	1	Stephens Prdctn CO	Stephens Prdctn CO 1-Walker Ruth	6N	31W	3
3131110220000	7	Oxley Petroleum CO	Oxley Petroleum CO 7-Walker Ruth	6N	31W	3
3131101400000	1	Stephens Prdctn CO	Stephens Prdctn CO 1-Condren	6N	31W	7
3131115300000	6	Stephens Prdctn CO	Stephens Prdctn CO 6-Condren	6N	31W	7
3131114600000	3	Stephens Prdctn CO	Stephens Prdctn CO 3-Condren	6N	31W	7
3131114920000	4	Stephens Prdctn CO	Stephens Prdctn CO 4-Condren	6N	31W	7
3131114000000	2	Stephens Prdctn CO	Stephens Prdctn CO 2-Condren	6N	31W	7
3131115180000	5	Stephens Prdctn CO	Stephens Prdctn CO 5-Condren	6N	31W	7
3131114010000	6	Stephens Prdctn CO	Stephens Prdctn CO 6-Johnson H L	6N	31W	8
3131101430000	1	Stephens Prdctn CO	Stephens Prdctn CO 1-Johnson	6N	31W	8
3131109380000	4	Stephens Prdctn CO	Stephens Prdctn CO 4-Johnson H L	6N	31W	8
3131114810000	8	Stephens Prdctn CO	Stephens Prdctn CO 8-Johnson H L	6N	31W	8
3131114210000	7	Stephens Prdctn CO	Stephens Prdctn CO 7-Johnson H L	6N	31W	8
3131113250000	5	Stephens Prdctn CO	Stephens Prdctn CO 5-Johnson H L	6N	31W	8

3131105020000	2	Sonat EXPLO INC	Sonat EXPLO INC 2-Skinner	6N	31W	9
3131101490000	1	Stephens Prdctn CO	Stephens Prdctn CO 1-Skinner	6N	31W	9
3131110260000	3	XTO Energy INC	XTO Energy INC 3-Skinner	6N	31W	9
3131105170000	1	Sonat EXPLO INC	Sonat EXPLO INC 1-First Western Property	6N	31W	10